REFUGIO OIL SPILL BIRD INJURY ASSESSMENT

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Introduction

This report provides an estimate of total bird mortality from the Refugio Oil Spill that occurred on May 19, 2015, from an onshore pipeline that ruptured and released oil that flowed into the Pacific Ocean and throughout the Santa Barbara Channel. Oil spill response coordination began the same day the spill was reported, and wildlife reconnaissance, recovery, transport, and rehabilitation teams were deployed starting May 20, 2015, and worked continually until wildlife field operations for birds were demobilized on June 24, 2015. Wildlife operations covered shorelines and near-shore environments between Gaviota and Redondo/Manhattan Beach. These wildlife operations were led by the California Department of Fish and Wildlife Office of Spill Prevention and Response, and the Oiled Wildlife Care Network with support from other agencies and organizations (Figure 1 and Figure 3).

Birds are vulnerable to oil spills for a variety of reasons including fouling of feathers, damaging skin and eyes, or creating internal physiological harm following ingestion or inhalation (Helm et al. 2015). Bird fouling by oil compromises the ability of their feathers to keep them warm in the cold Pacific Ocean water. For a species that forages in the water, even a relatively small amount of oil (e.g., the size of a nickel) may result in death. Like a hole in a wetsuit, the oil destroys the feathers' ability to insulate the bird, thus allowing cold ocean water to spread against the bird's skin. Birds that contact oil typically die of hypothermia and starvation. With their rapid metabolism, birds that are oiled cannot consume enough food to keep them warm and to also maintain the daily energy requirements they need to survive (Oka and Okuyama 2000). They can also ingest toxic amounts of oil while preening, as they attempt to clean themselves (Fry et al. 1986). Finally, larger amounts of oil can smother birds, affecting their mobility and ability to survive.

Shortly after the spill began, the Natural Resource Trustees (Trustees) created a Bird Technical Working Group, comprised of representatives from the California Department of Fish and Wildlife, U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration,

Bureau of Land Management[1], and University of California[2]. The group was responsible for developing and implementing the methodology for assessing injury to birds from the spill, and identifying and scaling appropriate restoration projects necessary to compensate for bird injuries.

Based on knowledge of the diversity of bird species and their use patterns within the spill zone, the Trustees sub-divided the injury assessment into three categories: 1) brown pelican injury; 2) western snowy plover injury; and 3) other bird injury. Brown pelicans were analyzed in a separate category due to the large numbers that were affected by the spill and because their body size allowed the Trustees to survey them in their breeding and non-breeding habitats to assess oiling rates and calculate injury in a way that was not feasible with other seabird species. Western snowy plovers were also analyzed in a separate category due to their status as "threatened" on the federal Endangered Species List, pursuant to the Endangered Species Act of 1973, as amended. All other birds were analyzed using methods that have been demonstrated to effectively characterize injury during past oil spills, and which are applicable to a broad range of species. The injury analysis relies on data collected by the Wildlife Branch of the spill response incident command and additional studies conducted specifically for the Natural Resource Damage Assessment (NRDA). A conceptual model of the bird injury assessment is shown in Figure 2.

Figure 1. Mike Harris of the California Department of Fish and Wildlife captures an oiled brown pelican during the response to the Refugio Beach oil spill. Photo Credit: Kenneth Song/Santa Barbara News-Press/ZUMA Wire

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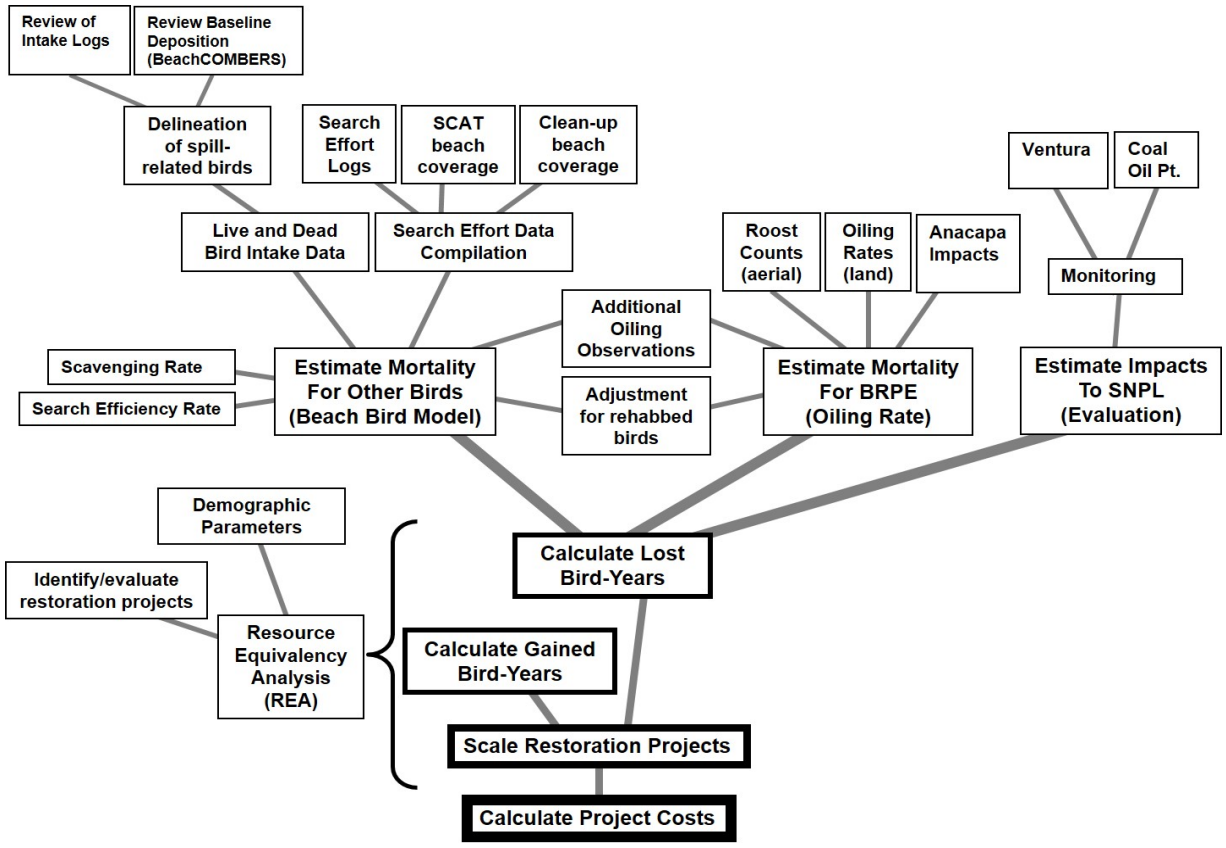


Figure 2. Conceptual model of the assessment of bird injury and restoration project scaling.

Data Collection and Studies

This section describes the data that was collected or analyzed by the Trustees in order to understand injury to birds from the spill. These data were generated by several efforts, including studies that were conducted by the spill response, data collected by the NRDA team, and studies that were not specifically developed for the spill response or the NRDA team but that provide relevant information for the understanding of injuries to birds from the spill.

Figure 3. Oiled western grebe captured along the Gaviota coast during the spill. Photo Credit: International Bird Rescue, 2015.

Wildlife Reconnaissance Aerial Surveys

On May 21, 2015, aerial surveys for pelagic birds were conducted roughly between Point Conception and the City of Goleta (Figure 4). The objective of these aerial surveys was to understand the general location and number of seabirds in the vicinity of the spill-affected area, in order to inform spill response activities. These surveys documented at least 13 unique pelagic bird species in groups ranging in size from a single individual to 120 individuals.

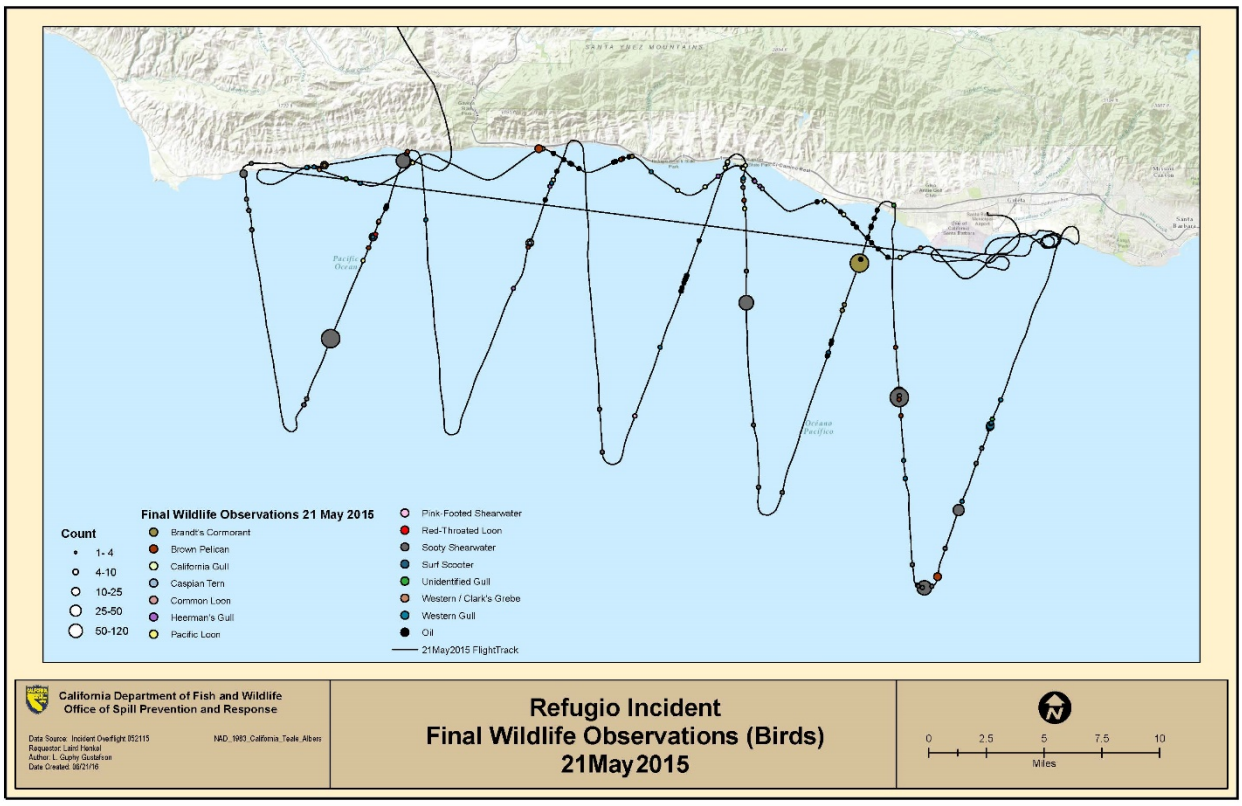


Figure 4. Observations of birds during overflights on May 21, 2015.

Live and Dead Bird Intake Data

Documentation of live and dead birds was collected as a normal part of the spill response. These data describe the collection of each bird, with such information as date, location, species, condition of bird, degree of oiling, etc. Locations of live and dead birds collected are shown in Figure 5, and details on the species collected are shown in Table 1.

During spill response operations all live distressed birds were taken to rehabilitation centers for further care. All dead birds encountered within the spill zone were collected. A total of 66 live birds and 203 dead bids comprised of at least 28 species were collected between May 20, 2015, and June 24, 2015 (OWCN 2015).

A portion of the live and dead birds collected during the spill may not have been injured or killed by the spill and/or response operations. The Trustees developed methods for analyzing the live and dead bird intake records to determine which animals were likely injured or killed by the spill and which were not. The details of this analysis are discussed below.

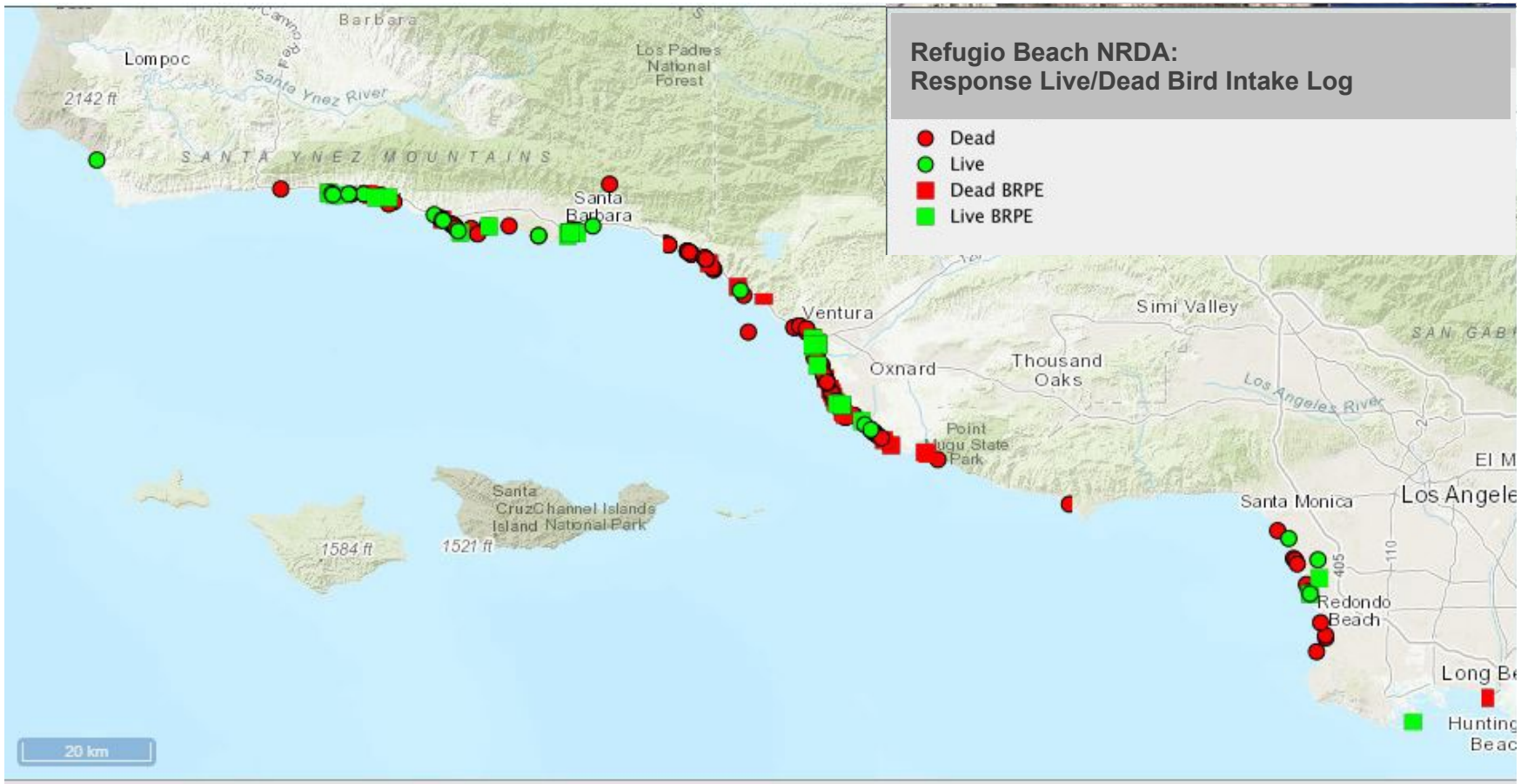


Figure 5. Location of live and dead birds recovered during wildlife operations segregated by brown pelicans (BRPE) and all other bird species. Two additional live pelicans were recovered from Newport Beach, outside the area represented in this map.

Table 1. All birds collected live and dead by species (or closest known taxon).

SPECIES	COLLECTED LIVE	COLLECTED DEAD	TOTAL
Black storm-petrel	0	1	1
Barn owl	0	1	1
Black skimmer	0	1	1
Brandt's cormorant	2	11	13
Masked/Nazca booby	0	1	1
Brown pelican	47	26	73
California gull	1	5	6
Cassin's auklet	0	1	1
Clark's grebe	0	2	2
Common loon	0	3	3
Common murre	5	33	38
Cormorant sp.	0	4	4
Double-crested cormorant	0	14	14
Domestic duck sp.	0	2	2
Eared grebe	0	1	1
Elegant tern	0	1	1
Forster's tern	0	1	1
Grebe sp.	0	3	3
Heermann's gull	0	3	3
Loon sp.	0	5	5
Mew gull	0	1	1
Northern fulmar	0	5	5
Pacific loon	6	17	23
Pelagic cormorant	0	2	2
Pigeon guillemot	0	1	1
Rhinoceros auklet	0	2	2
Rock pigeon (feral)	0	1	1
Red-throated loon	1	12	13
California scrub-jay	0	1	1
Shorebird sp.	0	1	1
Sooty shearwater	0	16	16
Surf scoter	1	2	3
Western grebe	1	8	9
Western gull	2	9	11
Unknown	0	6	6
TOTAL	66	203	269
TOTAL w/o brown pelican	19	177	196

Anacapa Island Brown Pelican Surveys

During the spill period, brown pelicans were nesting on Anacapa and Santa Barbara Islands, and were using the Santa Barbara Channel and mainland roosts for foraging, migrating, and resting. Surveys of brown pelicans at the Anacapa Island and Santa Barbara Island breeding colonies were conducted by the NRDA team to determine whether nesting brown pelicans were affected by oil from the spill. The surveys were conducted by boat and by ground, and are described further in the sections below.

Brown Pelican Roost Surveys

Due to their large size, pelicans can survive for many days after oiling. In order to assess the extent of oiling of brown pelicans, surveys of known pelican roost sites on the mainland from Morro Bay to Los Angeles were performed in the days immediately after the spill (Jaques et al. 2015). Surveys were conducted by the NRDA team by ground, boat, and air to determine the number and geographic distribution of pelicans and to observe the proportion of pelicans that showed signs of oiling.

Brown Pelican Rehabilitation Survival Studies

The Oiled Wildlife Care Network (OWCN) assisted with wildlife operations during the spill, including rehabilitation of oiled birds. In order to understand the survival rate of rehabilitated oiled wildlife, the OWCN and other collaborators tracked rehabilitated pelicans to determine their survival and distribution relative to birds that were not oiled and rehabilitated during the spill (Lamb et al. 2018). Prior to release, 12 oiled and rehabilitated pelicans were instrumented with solar-powered satellite GPS tracking devices, along with 8 control (unoiled) pelicans. All birds survived for at least 12 weeks. In the first 6 months after release, distance traveled and movements were similar between rehabilitated and control pelicans. Several individuals traveled >5000 km, migrating to northern California or central Oregon in late summer and early fall. In the spring, most birds traveled south, some as far as Baja California.

Mortality was documented among both rehabilitated and control birds; however, a majority of birds that stopped transmitting were never found. Lack of transmission could represent mortality, transmitter or battery failure, or transmitter loss. A major limitation of the study was unreliability of the technology. After 40 weeks of tracking, only 5 transmitters (3 rehabilitated and 2 control) were still transmitting. Field observations of color-banded birds documented at least five of the satellite transmitters that stopped transmitting did not do so because of mortality. Additional analysis is presented in Lamb et. al (2018) and Jaques et al. (2019).

Sandpiper Pier Cormorant Colony Surveys

Within the spill area, Brandt's cormorants nest on four platforms that were constructed offshore of Ellwood Beach in Santa Barbara County. Surveys were conducted by the NRDA team from the shore to assess the number and status of nests throughout the 2015 breeding season. The four nesting platforms were visited and photographed on May 22, May 28, and June 8, 2015. There were approximately 30 Brandt's cormorant (BRAC) nests on each platform.

In May, the nests were at a variety of stages; many had apparently incubating adults (the eggs were not visible from our vantage point) and some were feeding chicks. Between the May and June visits, we examined the photographs and identified 12 nests that: 1) had apparently incubating adults; and 2) were clearly visible (Figure 6). The 12 nests were surveyed for a final time on June 8, 2015, where chicks were observed in at least 8 of the nests. The status of the 12 nests on June 8, 2015 is described in Table 2. Based on these observations, the Trustees concluded that nests were not abandoned and chicks successfully hatched during the spill period. Adverse effects from exposure to oil were not visibly apparent during these surveys.

Figure 6. Cormorant nests on Platform 1 during a May 22, 2015 survey. Red circles indicate nests that were monitored during the May and June surveys. Photo Credit: NRDA team.

Table 2. Results of visual nest monitoring of 12 cormorant nets on June 8, 2015.

PLATFORM #	NEST #	OBSERVATION
1	1	Chick
1	2	2 chicks
1	3	Incubating but hunched up, possibly with little chick
1	4	2 chicks
2	1	Chick
2	2	Possibly giving up on incubating; adjusting nest
3	1	Chick
3	2	2 chicks
3	3	2 chicks
4	1	Incubating but hunched up, possibly with little chick
4	2	2 chicks
4	3	Incubating

Western Snowy Plover Studies

Western snowy plovers utilize several sandy beaches within Santa Barbara and Ventura Counties for nesting including Coal Oil Point Reserve, San Buenaventura State Beach, McGrath State Beach, Mandalay State Beach, Ormond Beach, Hollywood Beach, and Naval Base Ventura County at Point Mugu. Monitoring has generally been conducted at these sites since at least 2001, although not every site has continuous monitoring for each breeding season, and methods are somewhat varied between beaches. Some level of western snowy plover monitoring was conducted at each of these beaches during the 2015 nesting season (Coal Oil Point Reserve 2015, Hartley 2015, Barringer 2015, Frangis and Cox 2015). All nesting beaches are located in Ventura County, with the exception of Coal Oil Point Reserve in Santa Barbara County.

During the cleanup, staff of the University of California Natural Reserve worked closely with response staff assigned to cleanup Coal Oil Point to minimize injury to western snowy plovers by identifying safe access routes, monitoring the birds' behaviors to determine their response to increased activities on the beach, and to provide recommendations to cleanup workers to help achieve a balance between removing the oil from the beach and creating conditions for successful nesting in the 2015 breeding season. The spill-specific monitoring and adaptive cleanup process is described in Nielsen et al. (2017) and summarized in the western snowy plover injury analysis below.

Figure 7. Western snowy plover at Coal Oil Point during cleanup operations. Photo Credit: Jessica Nielsen, UCSB.

Baseline Beached Bird Studies

Information about the baseline rate of bird deposition on beaches throughout the spill zone is available from information collected through the Beach Coastal Ocean Mammal and Bird Education & Research Surveys (BeachCOMBERS) program. The program utilizes highly trained citizen scientists to conduct monthly beach surveys using a dedicated protocol for documenting the number and status of beached birds and mammals within each survey segment. Data collected include species identification, decomposition state, observations of carcass scavenging, observations of carcass oiling, and other factors. All carcasses encountered during a survey are marked to identify whether the carcass has been observed on previous surveys (a new mark is made each month). The goal of the BeachCOMBERS program is to establish long-term data on baseline bird and mammal stranding rates, so that when unusual mortality events occur (e.g., oil spills, domoic acid events, etc.), resource managers can understand and explore the magnitude and cause of the bird and/or mammal mortality. The spill occurred within the area monitored by the South Coast Chapter of BeachCOMBERS (Figure 8), which began collecting monthly data in January 2013.

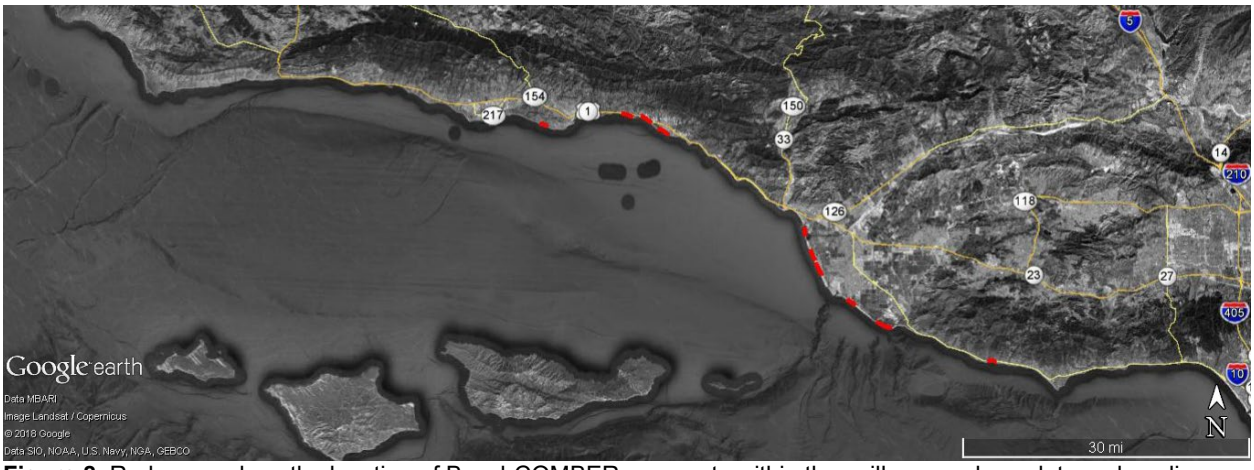


Figure 8. Red areas show the location of BeachCOMBER segments within the spill zone, where data on baseline deposition of birds and mammals was collected prior to May 2015.

Brown Pelican Injury Analysis

Brown pelicans were the most numerous bird species to be found alive and dead during the spill period. Of the birds collected during the spill, 72% of the live birds (n=47), and 13% of the dead birds (n=26) were brown pelicans. Not all of the live and dead brown pelicans affected by the spill were captured or collected. Brown pelicans are capable of long-distance flights and oiled pelicans can survive for several days to weeks before becoming weak and either succumb to their exposure or become lethargic enough to be captured. To estimate the total number of brown pelicans injured by the spill, the Trustees applied the following methodology which will be discussed further in the sections below.

1) Determine brown pelican distribution during the spill;
2) Determine brown pelican oiling rate;
3) Calculate brown pelicans injured within the spill response zone;
4) Calculate brown pelicans injured outside the spill response zone (missed by the response);
5) Adjust for rehabilitated birds; and
6) Calculate total BRPE injured.

Brown pelican biology and distribution during the spill

The California brown pelican is a subspecies of brown pelican that ranges throughout the west coast of North America. It nests in Mexico and on the Channel Islands. The California brown pelican was delisted by the state of California in June 2009 and by the federal government in December 2009. Brown Pelicans typically forage in relatively shallow coastal waters, feeding almost entirely on surface-schooling fish caught by plunge diving. Brown pelicans are rarely found away from salt water and do not normally venture more than 32 kilometers (20 miles) out to sea. During the non-breeding season, brown pelicans roost communally on offshore rocks and structures such as piers and wharfs. Brown pelicans have wettable plumage, so they must have roost sites to dry after feeding or swimming (Jaques and Anderson 1987). Roost sites are also important for resting and preening. The essential characteristics of roosts include: nearness to adequate food supplies; presence of physical barriers to protect the bird from predation and

disturbance; sufficient surface space for individuals to interact normally; and adequate protection from adverse environmental factors such as wind and surf (Jaques and Anderson 1987).

Brown pelicans on the Channel Islands

Anacapa Island, the second smallest of five Channel Islands, is home to the largest breeding colony of California brown pelicans in the United States. Brown pelicans create ground nests in dense colonies within the cliffs and canyons of the Channel Islands (Figure 9). The only other significant U.S. breeding colony is located on Santa Barbara Island, which is much further from the mainland and is unlikely to have been heavily impacted by the spill. A much larger number of pelicans breed in Baja California, Mexico. After breeding, many of these birds migrate north and make up the majority of pelicans along the U.S. west coast in summer and fall. During the oil spill, many of the Baja pelicans were already migrating north, due to a failed breeding season in Mexico, and were passing through the spill zone. Based on the results of a radio transmitter study of rehabilitated pelicans (funded by the OWCN and not through NRDA; see below), it appeared that pelicans from both Anacapa and Baja were impacted.

Reconnaissance level, boat-based surveys of the brown pelican nesting colony on Anacapa were conducted by Channel Islands National Park staff in June and July 2015 during the initial response effort (Larramendy et al. 2018). The surveys were conducted by boat to visually inspect brown pelicans that were visible from the water, and did not include direct, on-island, access. Visibly oiled pelicans were not observed on Anacapa Island during these surveys. Ground surveys provide a more comprehensive means of identifying oiled pelicans, but are highly disruptive to nesting and fledging activities, and were only scheduled after the end of the breeding season.

Ground surveys were conducted on September 20 and 21, 2015, on West Anacapa Island and Middle Anacapa Island, where a majority of the brown pelican nesting activity occurs (Larramendy et al. 2018). During these surveys, biologists inspected the remains of nests that were active during the spill period and the nests were marked and tallied per standard NPS methods. Surveys on day one focused on West Anacapa Island, where a majority of brown pelican nesting occurs; day two covered Middle Anacapa Island and East Anacapa Island. Hundreds of nests were inspected for oiling. Evidence of oiling was limited to one juvenile brown pelican carcass on Middle Anacapa Island, in which a small amount of weathered oil was found on several wing tips, and a few specks on the downy feathers around its shoulder (Figure 10). The survey team estimated the bird was about 6 weeks of age at the time of death, which is essentially full grown. Based on these efforts, the Trustees concluded that brown pelican nesting activities on the Channel Islands were not substantially affected by the Refugio Beach Oil Spill.

Figure 9. Brown pelicans nesting. Photo Credit: A. Yamagiwa 2017 as presented in Larramendy et al. 2018.

Figure 10. Brown pelican chick carcass identified on middle Anacapa Island during a September 2015 ground survey with oil observed on its feathers. Photo Credit: Chris Dunn, Padre Associates.

Determination of brown pelican oiling rate

Brown pelicans along the mainland coast between San Luis Obispo County and northern Los Angeles County were surveyed by ground on 11 days in May and June of 2015; and by air on May 27, 2015. Ground surveys allow for visual inspection of brown pelicans to identify visible oiling; however, for large roost sites it is not possible to accurately document the total number of individuals because only a portion are visible from ground-based vantage points. Similar to ground surveys, boat surveys were conducted of roost locations such as the jetties of the Ventura Harbor to visually inspect pelicans for oiled plumage in these locations that are not accessible by ground.

During each survey, the total number of pelicans visible and the number of individuals that showed visible oiling were documented. From those data, the percent of oiled individuals was calculated. For roosts where surveys were conducted from multiple vantage points observing the same population, the oiling rate ("percent oiled") was averaged over all observations for that location within a single day. For roost locations that were surveyed on multiple days, the day with the highest maximum oiling rate was selected as the maximum oiling rate ("Maximum % Oiled"). For example, the oiling rates at Santa Barbra Harbor were 6.4% on May 23, 8.2% on May 24, and 10.8% on May 25. For the Santa Barbara Harbor, 10.8% was used as the maximum oiling rate for that roost location. In general, oiling rates decreased with time and proximity to the spill.

The aerial survey of pelican roosts conducted on May 27, 2015 consisted of photographing brown pelicans at all roost sites and counting individuals from the aerial images (Jaques et al. 2015). Aerial surveys are ideal for documenting the total number of individuals at each roost by taking photographs and counting brown pelicans (which are easily distinguishable from other birds due to their body size) at each roost. A total of 6,862 brown pelicans, 90% of which were in adult plumage, were counted at 29 roost sites (Figure 11). The largest concentrations of pelicans were at Shell Beach and Pismo Beach to the north of the spill site and at Rincon Island and Ventura Harbor to the south (Jaques et al. 2015).

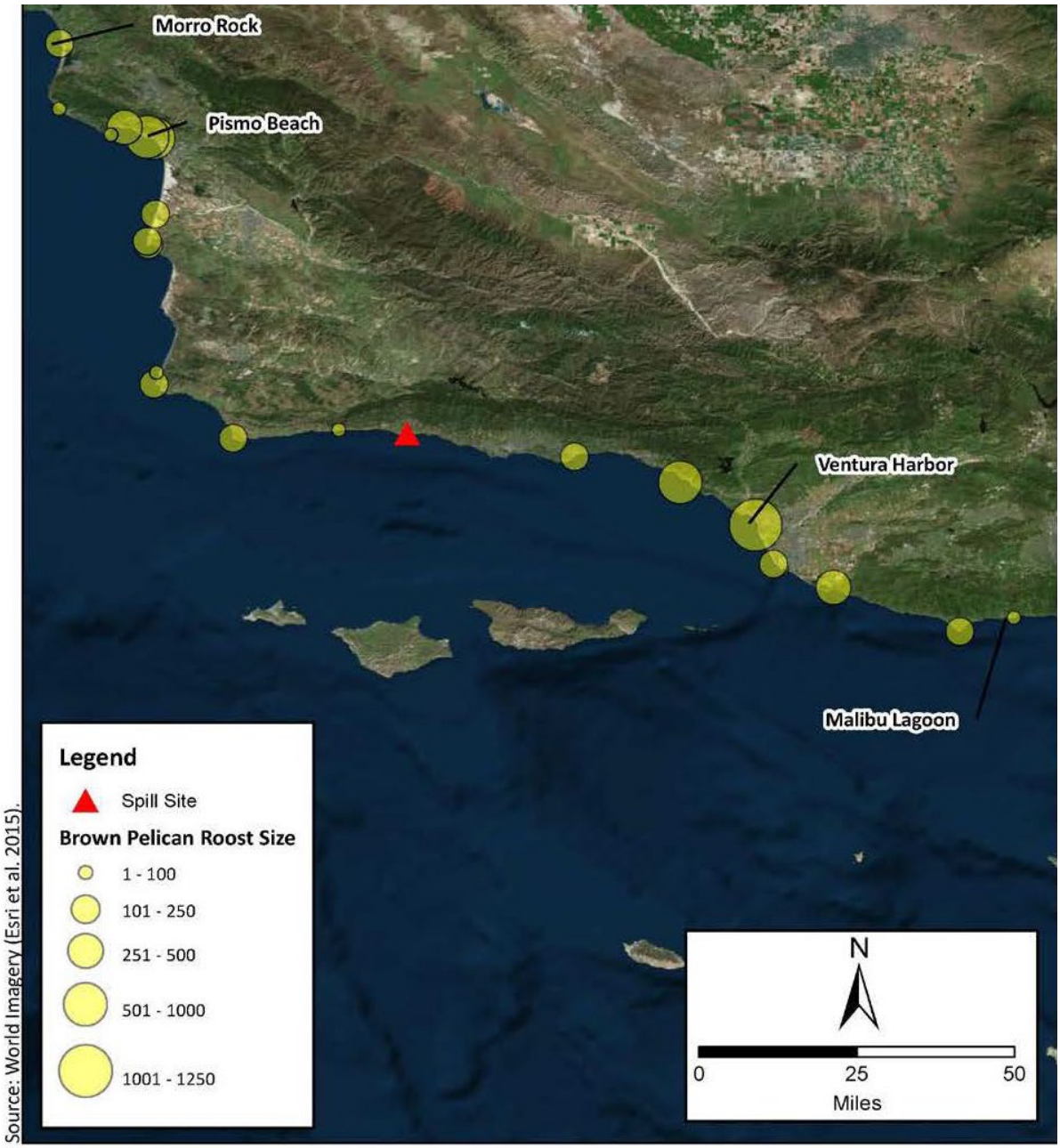


Figure 11. Results of aerial surveys of brown pelican roosts conducted on May 27, 2015. (Jaques et al. 2015)

Because no single survey method is able to detect both the proportion of oiled individuals at any given roost and the total number of individuals at the roost, the Trustees analyzed these datasets together to approximate the total estimated oiling at each roost site.

The Trustees used the maximum oiling rate ("percent oiled") at each roost site north of the spill zone and multiplied the oiling rate by the number of pelicans observed at each roost during the aerial survey (Table 3). Three substantial roost locations (Morro Bay, Santa Maria River/Point Sal, and Gaviota) were unable to be assessed for oiling rate because they were inaccessible by ground/boat or because the total number of observable pelicans was too low ($n < 5$) to provide a

meaningful assessment. For these sites, the oiling rate was estimated by taking the average of the oiling rate at the roost site to the north and to the south. For Morro Bay, where no oiling rate was available to the north, the oiling rate was estimated to be half of the oiling rate calculated from the roost location to the south.

Table 3. Location and results of brown pelican surveys conducted between May 20 and June 9, 2015. Percentages (% oiled) represent the average oiling rate of brown pelicans at each roost site on each day. The number of brown pelicans at each roost site was documented by aerial surveys on May 27, 2015. The number of oiled pelicans was calculated by multiplying the maximum oiling rate (%) by the number of pelicans at each roost site.

	Morro Bay	Pismo/Shell Beach	S. Maria/ Pt. Sal	Vandenberg	Gaviota	S.B. Harbor	Rincon	Ventura/Oxnard	Malibu	
% oiled - 5/20/2015				**7.3%**						
% oiled - 5/23/2015		**5.9%**				6.4%				
% oiled - 5/24/2015						8.2%				
% oiled - 5/25/2015						**10.8%**	**1.9%**			
% oiled - 5/26/2015								**1.1%**	**2.0%**	
% oiled - 5/27/2015				2.9%						
% oiled - 5/28/2015								0.9%		
% oiled - 6/4/2015				0.0%						
% oiled - 6/8/2015								0.0%	0.0%	
% oiled - 6/9/2015						0.0%				
Max Oiling rate (%)	**3.0%**	**5.9%**	**6.6%**	**7.3%**	**9.0%**	**10.8%**	**1.9%**	**1.1%**	**2.0%**	**TOTAL**
# Pelicans at each Roost	**159**	**2681**	**794**	**381**	**59**	**139**	**748**	**1740**	**161**	**6,862**
# Oiled (calculated)	**5**	**159**	**53**	**28**	**5**	**15**	**14**	**20**	**3**	**302**

Brown pelican injuries within the spill response zone

Wildlife reconnaissance, recovery, transport and rehabilitation was conducted as part of the spill response operations. During the response, 47 brown pelicans were captured live and 26 were collected dead, for a total of 73 (OWCN 2015). The live birds were sent for rehabilitation, as described further below. Dead brown pelicans were collected and examined to determine carcass condition, extent and location of oiling, and extent of scavenging. One dead pelican was determined to have likely died prior to the spill because the decomposition state was considered to be too advanced at the time of collection to be spill related.

To determine how well observations of oiled pelicans at roost sites correlated with the number collected live and dead at each location, the Trustees compared the number of pelicans collected during the response with the number of oiled pelicans documented at roost sites within the response zone. For this analysis, the Trustees used the roost survey results (Table 3) and compared these to the number of brown pelicans collected by wildlife operations during the response. In the region of brown pelican roost sites south of the spill origin (Santa Barbara Harbor through Los Angeles), the response generally collected as many or more pelicans than were observed oiled during the roost surveys (Figure 12). From these data, the Trustees infer that the observation of oiled pelicans at roost sites is a conservative indicator of pelicans injured at that location.

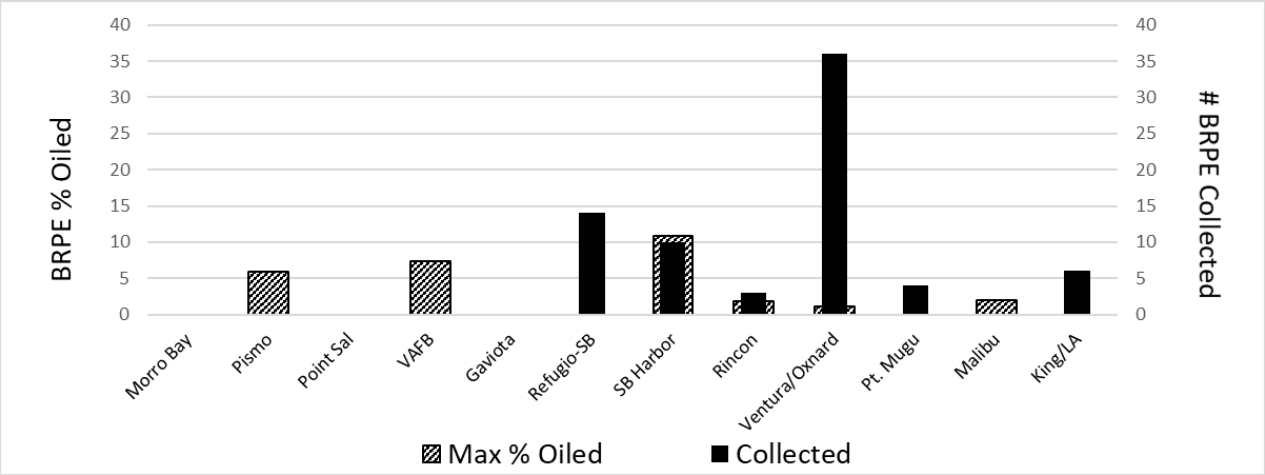


Figure 12. Brown pelicans collected live and dead at each location (black) and percent of brown pelicans observed oiled at each roost location (striped).

Brown Pelicans Missed by the Spill Response

During the time of the spill, brown pelicans within the spill zone were generally migrating north toward Oregon, Washington, and Canada, from breeding grounds in Mexico and on the Channel Islands, although movement patterns can be quite varied. This northward migration created the likelihood that brown pelicans may have been exposed to Refugio spill oil in the spill-affected area and carried it north, outside of the area that was surveyed for oil and oiled wildlife. No wildlife reconnaissance and recovery efforts were carried out by the response north of Gaviota; however the roost surveys indicated that oiled pelicans were found north of the spill response zone. When comparing the population distribution of brown pelicans at roost locations on May 27, 2015, to the location of collected birds throughout the spill response, it appears that more pelicans were present north of the spill zone, but response actions were only occurring to the south (Figure 13).

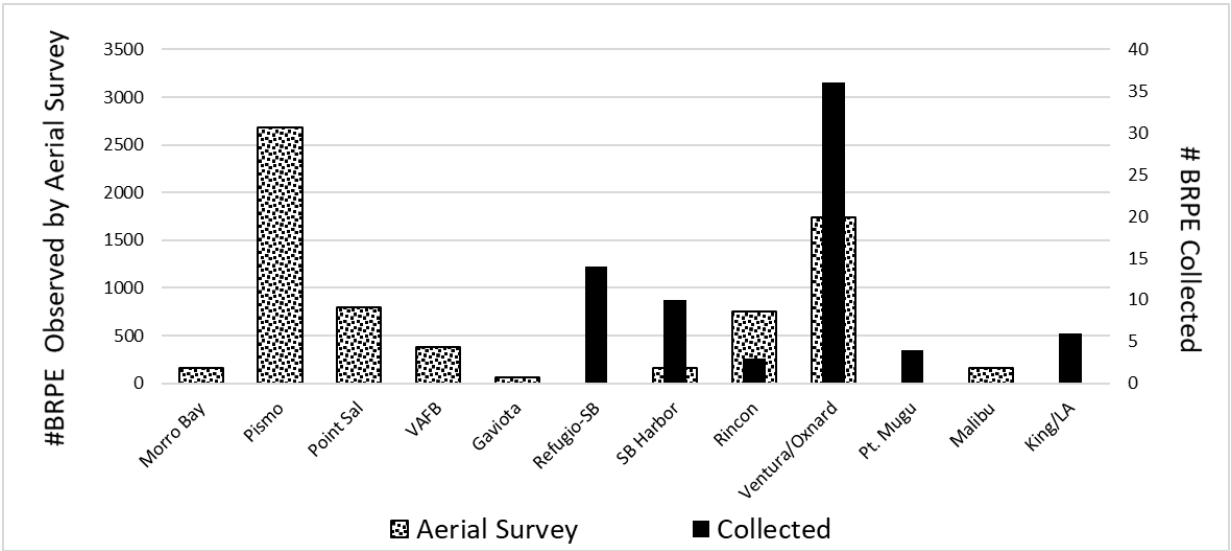


Figure 13. Brown pelicans observed at roost sites between Morro Bay and Malibu (speckled) compared with brown pelicans collected live and dead during the response (black).

These data suggest that a substantial number of brown pelicans affected by the spill were missed by the response. The Trustees estimated the number of injured brown pelicans that were affected by the spill, but traveled north outside the response area, by utilizing the observations of oiled pelicans at roosts north of the response area, and applying the ratio of observed oiled birds to collected birds observed throughout the spill response zone.

Based on the observation that oiled pelicans at roost sites is a conservative indicator of pelicans injured at that location, the Trustees developed a correction factor to determine the total number of injured birds using the roost survey data. To develop this correction factor, the Trustees compared the estimated number of oiled brown pelicans calculated at roost sites within the response area and compared that estimate with the total number of brown pelicans collected by the response at Santa Barbra Harbor or points south (Figure 14). This yielded a ratio of 58:52 (birds collected : birds estimated), resulting in an estimated 279 brown pelicans missed by the response.

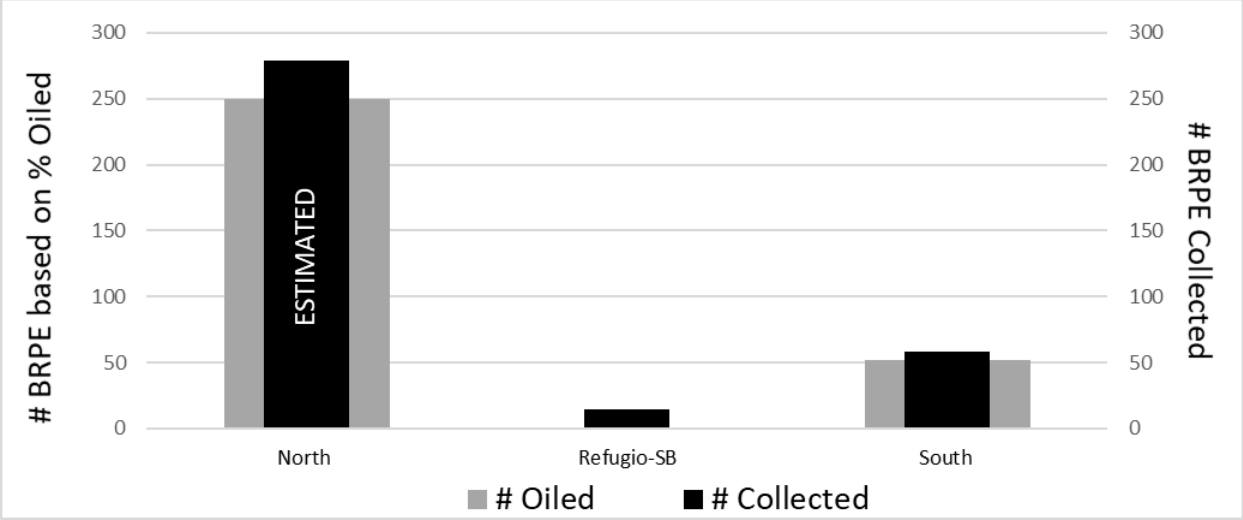


Figure 14. Estimated brown pelican injury north of the response area, based on the observed ratio between oiled birds at roosts within the response zone and the number of brown pelicans actually collected in those areas.

Rehabilitation Credit

During the spill response 47 brown pelicans were recovered and transported to rehabilitation centers for treatment. Of these 47 birds, 4 died in care and 43 were released. The post-release survival study was hampered by failure of some of the tracking equipment; however, field observations of color-banded birds, and results of the transmitter study indicated that all birds survived for at least 12 weeks, and some greater than one year (Lamb et al. 2018). Based on these findings, the Trustees are assuming that rehabilitated birds that were released survived 75% as well as wild birds that were unaffected by the spill, resulting in a rehabilitation credit of 32 birds as shown below.

Collected Live: 47
Rehabbed and released: 43
Survival Rate (assumed): 75% of natural survival rate
Rehabilitation Credit: 43 birds x 75% = **32** birds

Total Brown Pelican Injury

Based on the number of pelicans recovered live and collected dead during the response, the estimated number of pelicans injured by the spill but missed by the response, and the rehabilitation success of pelicans that were treated and released, the Trustees estimate that a total of 319 brown pelicans were injured by the Refugio Oil Spill.

Table 4. Total brown pelican injury from the Refugio oil spill.

Brown Pelicans injured within the spill response zone	72
Brown Pelicans missed by the spill response	+ 279
Rehabilitation credit	- 32
TOTAL Brown Pelican Injury	319

Western Snowy Plover Injury Analysis

When the spill occurred, federally threatened western snowy plovers were in the midst of their breeding season, with many chicks recently hatched and foraging on sandy beaches. Western snowy plovers are among very few species that nest directly on sandy beaches, which makes them vulnerable to conflicts with human activities. In the spill zone, there are several locations where plovers nest: Coal Oil Point Reserve (COPR) at University of California Santa Barbara, San Buenaventura State Beach, McGrath State Beach, Mandalay State Beach, Hollywood Beach, Ormond Beach, and Naval Base Ventura County at Point Mugu (Figure 15). All these locations are within "Recovery Unit 5" as outlined in the U.S. Fish and Wildlife Service's Western Snowy Plover Pacific Coast Population Recovery Plan (USFWS 2007). Population surveys are conducted each year during the same time period for each breeding location, creating a dataset of "summer window surveys" (USFWS 2018). The average population counted during the summer window surveys between 2014 and 2017 at each of these beaches is shown in Figure 15.

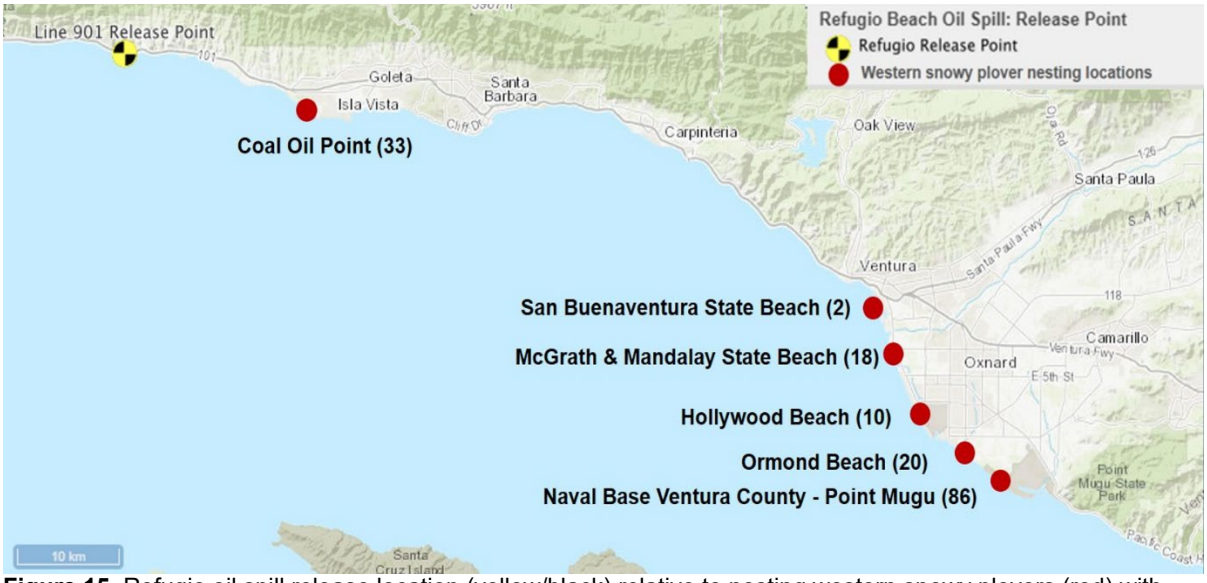


Figure 15. Refugio oil spill release location (yellow/black) relative to nesting western snowy plovers (red) with average number of adults counted during summer window surveys between 2014 and 2017 in parenthesis.

All of the beaches shown in Figure 15 received oiling and/or tar balls in varying degrees during the spill. The maximum amount of oil observed by Shoreline Cleanup Assessment Teams (SCAT) ranged from heavy at COPR to very light at Ormond. The presence of cleanup crews corresponded to the degree of oiling (Table 5).

Because western snowy plovers forage on invertebrates that live in the beach-cast wrack, resource managers sought to protect the plovers from four different impacts: 1) direct exposure to oil; 2) exposure via the ingestion of oiled prey; 3) the loss of wrack which serves as the primary habitat for their prey; and 4) disturbance by cleanup crews.

These goals led to tradeoffs between competing strategies. Cleanup crews removed oil from the beach, but also caused disturbance to both adult plovers and young chicks. Wrack removal reduced the risk of exposure to oil, but also eliminated the primary foraging habitat for shorebirds. Resource managers sought to balance these tradeoffs by intensive monitoring of the plovers and close communication with and education of cleanup crews. As COPR was exposed to the greatest oiling and most intense response activities of any plover breeding sites within the spill zone, it was also the most intensively studied to determine injury to plovers from oil exposure and response actions.

Table 5. Oiling and response activities at representative beaches that support nesting for western snowy plovers, showing a longer duration where cleanup crews were present at Coal Oil Point, compared to breeding sites in Ventura County where more limited cleaning was necessary.

Beach	SCAT max oiling	Cleanup crews present
Coal Oil Point Reserve	heavy	17 of 20 days May 24 – June 12
McGrath State Beach	light	6 of 9 days May 31 – June 8
Hollywood Beach	light	7 of 9 days May 31 – June 8
Ormond Beach	very light	3 of 4 days June 4 – June 7

Injury to plovers from response actions, wrack removal, and food web impacts at San Buenaventura, McGrath, Mandalay, Hollywood Beach, Ormond Beach, and Point Mugu are incorporated into the assessment of injury to sandy beach habitats described in other sections of the Damage Assessment and Restoration Plan (DARP). At these Ventura County nesting beaches, observations of direct exposure to oil were limited to Hollywood beach, but all nesting beaches were affected by some level of Refugio incident oil.

Effect of the spill on western snowy plover population size at COPR

A complete overview of the studies implemented to assess western snowy plover injury at COPR is presented by Nielsen et al. (2017) and is summarized in the sections below. Cleanup efforts started at COPR on May 24, 2015, after the staff at COPR determined that there was enough oil on the beach to warrant cleanup. To reduce the impact of the cleaning activities on the plovers, each crew was supervised by an observer, a biologist or a volunteer bird expert. Biological observers were assigned to monitor all plover nests during cleanup activities. The observers asked the crew to move away if the females incubating the nest left the nest for more than 5 minutes. After the female returned to the nest, the crew could come back, often with fewer workers, to avoid another disturbance.

To study whether the oil spill or cleanup efforts affected the population of plovers at COPR, all adults, chicks, and nests, were counted several times each week, during the entire breeding season in 2015. The beach at COPR is narrow, so the observers could easily count while walking along the wet sand and looking towards the upper beach where the nests and chicks rest. The COPR staff have counted the plover population 3 times a week every breeding season since 2000.

The population of adult western snowy plovers at COPR remained around 20 individuals throughout May, June, and July of 2015. It was not known if any died, but no dead western snowy plovers were found. Observers did not enter the fenced nesting area to avoid disturbing the nests and chicks. The long-term population data are shown in Figure 16 (COPR 2018).

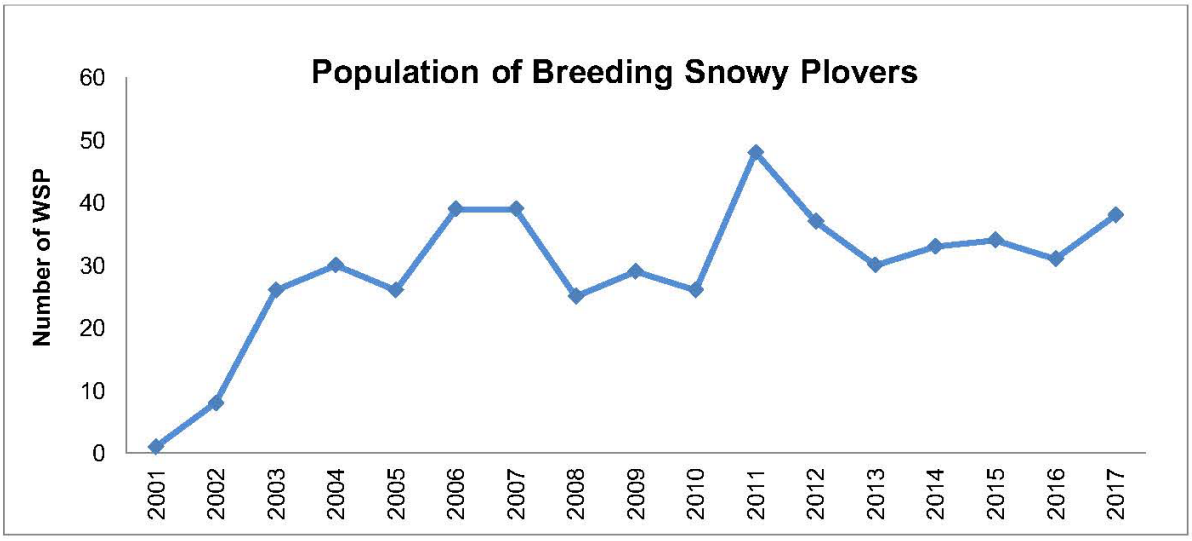


Figure 16. Population of breeding western snowy plovers at Coal Oil Point Reserve between 2001 and 2017.

Changes in western snowy plover behavior during cleanup activities at COPR During the last 3 cleanup days in June 2015, the COPR staff did not interfere with the cleanup efforts to study how those activities affected the western snowy plovers at the site. To study the effect of the cleaning crew on nesting behavior, the observers recorded the time that incubating western snowy plovers were on and off the nest, on days with or without crews, at approximately the same time of the day and under the same weather conditions. The nesting area of the COPR is marked every 5 meters with a post and number so the location of the crew could be recorded by looking at the closest beach marker.

The presence of the cleanup crew influenced the behavior of nesting parents. COPR staff investigated two metrics: (1) the number of times a parent fled their incubating nest and (2) once disturbed, the amount of time a parent remained off its nest. Western snowy plovers were twice as likely to leave their active nest during oil spill cleanup. The average number of nest disturbances per hour with a cleanup crew present (4.2 disturbances ± 0.66) was significantly higher (p-value = 0.0226) than during the period without a cleanup crew present (2.1 disturbances ± 0.33). Furthermore, nesting snowy plovers remained away from their nest nearly three times longer when the cleanup crew was present. During the oil spill cleanup, the length of time the western snowy plovers spent away from the nest (8.3 minutes ± 1.9) was significantly

higher (p-value = 0.0321) than when the cleanup crew was absent (3.0 minutes ± 0.71). Western snowy plovers were approximately eight times less likely to feed when cleanup crews were present.

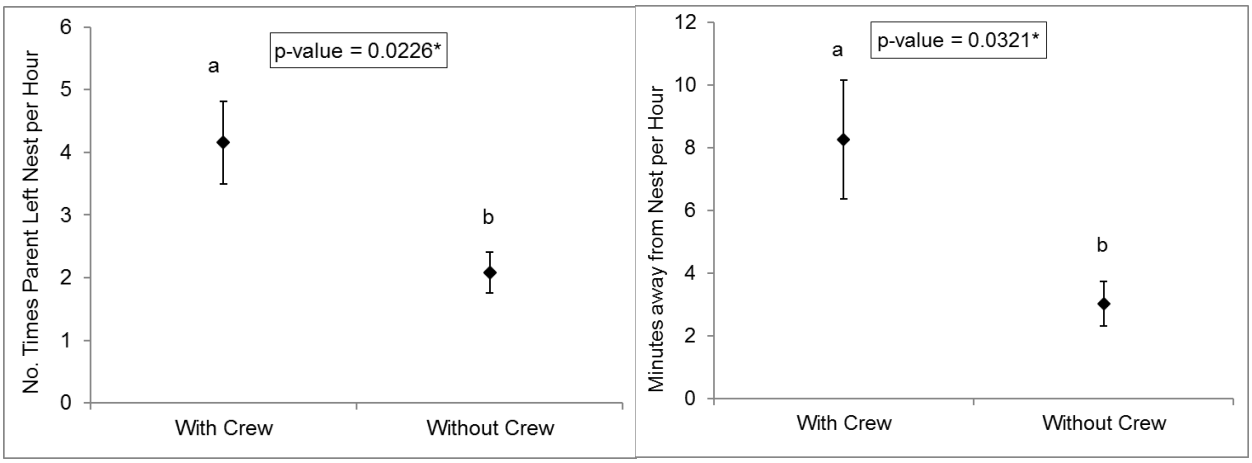


Figure 17. Number of times western snowy plover parents left the nest and total time away from nests with and without the presence of oil spill cleanup crews.

Effects of the spill on breeding success at COPR

In 2015, 62 western snowy plover nests were found at CORP and 34 of these nests hatched, resulting in a 55% hatching rate, which is above the long-term average (COPR 2015). From those 62 nests, 45 chicks fledged (Figure 18). The fledging rate (nests that fledged at least 1 chick, divided by the total number of nests that hatched at least 1 chick) was 78%, the highest it had been since 2009, as shown in Figure 19 (COPR 2015).

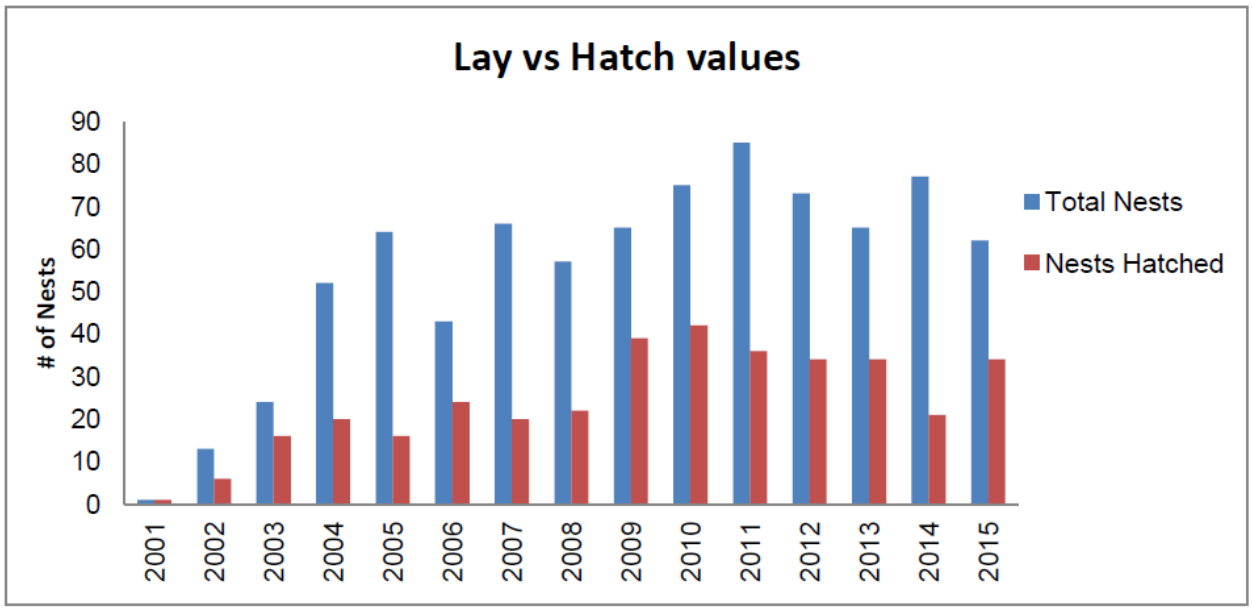


Figure 18. Nests laid (blue) compared with nests hatched (red) at Coal Oil Point between 2001 and 2015 (COPR 2015).

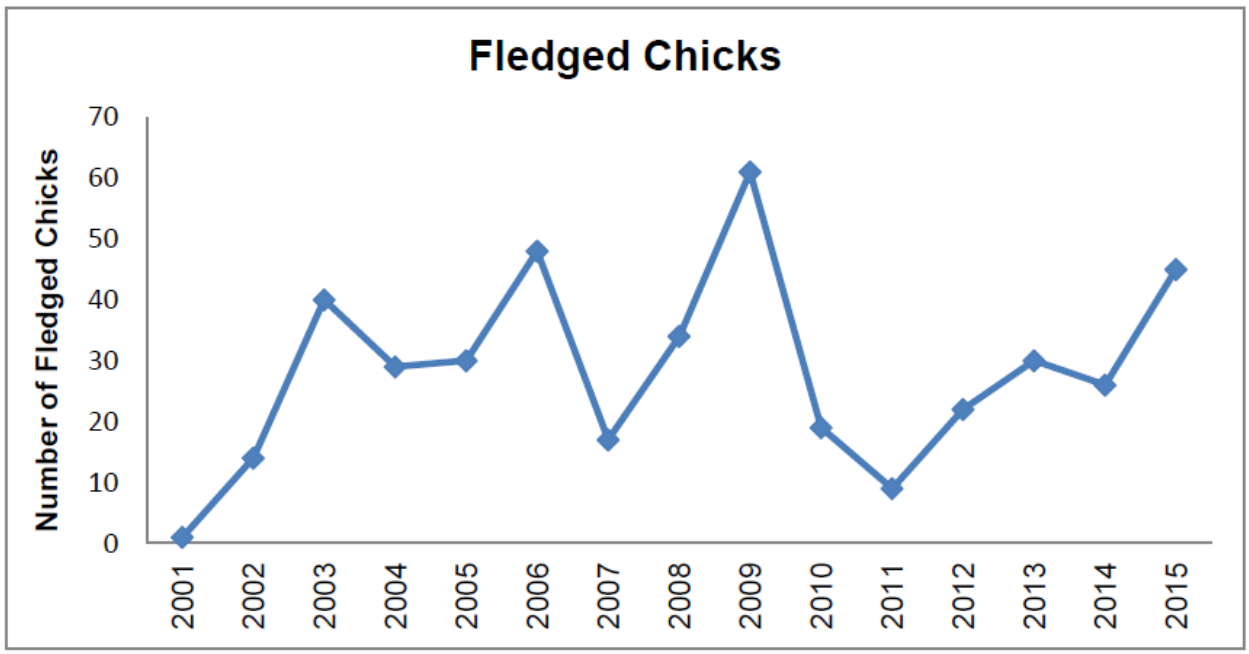


Figure 19. Number of chicks fledged from all nests each year at Coal Oil Point between 2001 and 2015 (COPR 2015).

Effects of the spill on body oiling at COPR

Unlike birds that dive in the water, western snowy plovers are exposed to oil while walking on the beach, bathing in shallow water, or foraging in and around kelp on the beach. To measure the amount of oiling on the western snowy plovers at COPR, each adult western snowy plover was photographed a total of 5 times during a 5-week period following the oil spill and again 2 months later (Figure 20). In the period following the oil spill through early June, the average percentage of western snowy plovers with oil on their body and bills was 37% and 41%, respectively. In late July, the percentage of western snowy plovers with oil on their body reduced to 4%, and percentage of western snowy plovers with oiled bills was 0% (Figure 21). This indicates that the occurrence of oil on the body and bills of western snowy plovers is likely attributed to the spill. The percentage of western snowy plovers with oil on their feet remained similar with 87% during the spill period and 76% in late July. As COPR is in close proximity to active oil seeps, the presence of weathered seep oil on COPR is common, and some level of oiling on plover feet is expected. Oil from the spill was fresh crude that was much less weathered and degraded when it arrived on COPR beaches, making it more "sticky" than weathered oil that typically washes up at COPR.

Figure 20. Sample photographs used for oiling analysis of western snowy plovers at Coal Oil Point. A clean plover is shown on the left, and an oiled plover is shown on the right. Photo credit: COPR 2015.

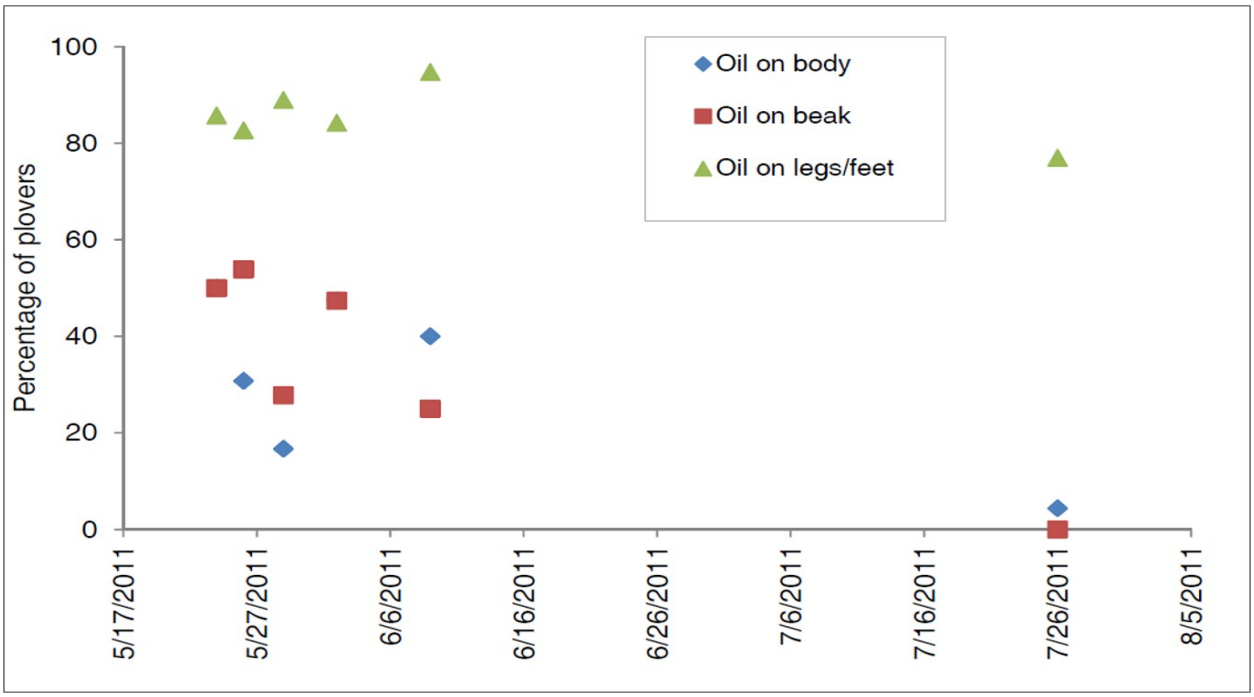


Figure 21. Results of photographic analysis of western snowy plover oiling on the body, beak, and feet/legs indicate that in the weeks immediately following the spill, over half of western snowy plovers at Coal Oil Point Reserve had oil on the beak and/or body, as compared with extremely low observations of oil on beak and/or body two months after the spill.

Risk of toxicity from oil ingestion

In order to understand whether the body and beak oiling document on western snowy plovers at COPR could cause harm to the birds, the Trustees conducted a screening level risk assessment using toxicity reference values identified in literature, and calculated oil exposure estimates by summing adult daily dietary and preening doses (Donohoe 2017). Fry et. al (1986) showed a negative relationship of external oiling of Santa Barbara crude oil on long-term fertility of wedge-tailed shearwaters, which were used as a surrogate for western snowy plovers in this analysis.

The results of this risk assessment indicated that the maximum calculated oil ingestion by western snowy plovers was over 8 times higher than levels that were documented to cause reproductive toxicity in shearwaters. Because over 70% of the season's nests had eggs that were already laid by the time oil reached the beach in 2015, it is unlikely that oil ingestion affected infertility in that year. Instead, the effects manifested a year later, which was the first time most birds had laid eggs since the spill. This delayed effect of oil ingestion on infertility rates has been documented in other birds (Fry et. al 1986). Because western snowy plovers at COPR are not banded, it was not possible to compare oiling on individuals to the fertility of those individuals in subsequent years. Despite the availability of fertility data for individual birds over time, a plausible connection between oil ingestion via preening and feeding and the increase in egg infertility in western snowy plovers at CORP the following breeding season was demonstrated.

Effects of the spill on western snowy plover fertility at COPR

Each year, western snowy plover eggs that don't hatch are opened by COPR staff to determine if the eggs were infertile (yolk intact), or had dead embryos. This procedure was continued during the oil spill response (2015) and subsequent years. The rate of infertile eggs fluctuates from year to year with an average of 2.13% infertility between 2001 and 2015 (n=1,785) (COPR 2018) (Figure 22). During the first breeding season after the oil spill, in 2016, the egg infertility rate increased to 9.56%, more than four times the average at COPR. In 2017, the egg infertility rate was higher than average at 3.95% but had decreased to a level more consistent with what had been observed prior to 2015 when the spill occurred. As described above, the increased levels of infertile eggs and dead embryos in the years following the spill may represent continued effects of the 2015 spill on plover reproduction.

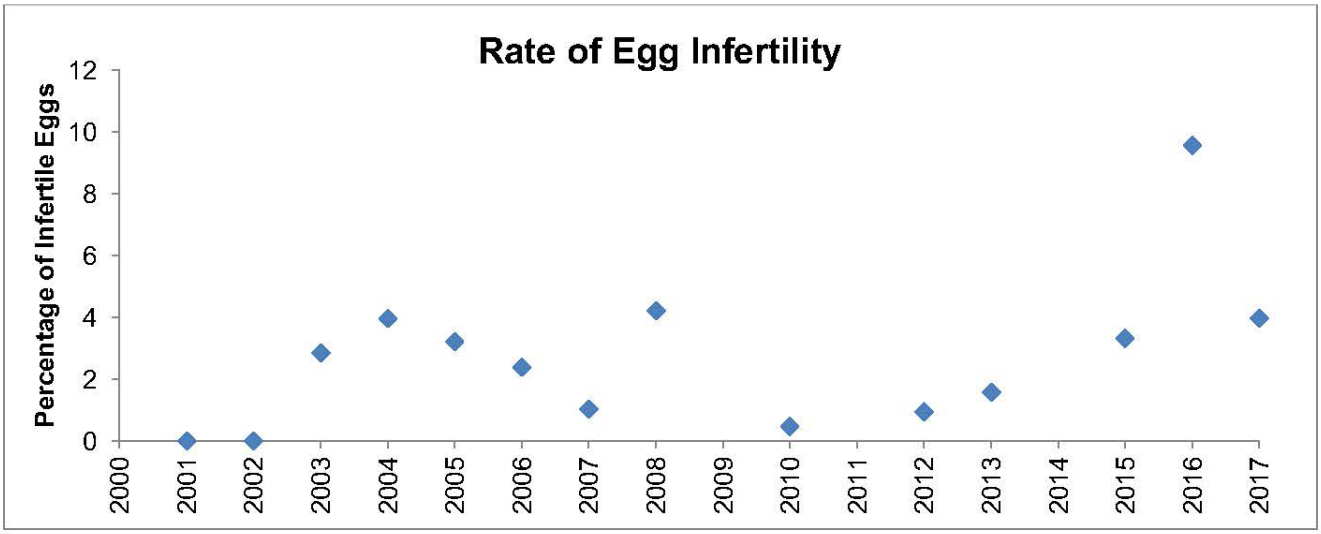


Figure 22. Percentage of infertile eggs by year (COPR 2018).

Effects of the Spill on Western Snowy Plovers at Other Locations

Western snowy plovers also nested in 2015 at San Buenaventura, McGrath, and Mandalay State Beaches in Ventura County (Frangis and Cox 2015), as well as Ormond Beach, Hollywood Beach, and Naval Base Ventura County, Point Mugu. One oiled western snowy plover was reported at Hollywood Beach (Barringer 2015). Farther south at Ormond Beach, no oiled

western snowy plovers were observed, but the beach was oiled (Hartley 2015). At all of these Ventura County breeding sites where cleanup occurred, crews may have affected western snowy plover behavior resulting in minor decreases to reproductive success. Western snowy plovers also may have been oiled but not detected, and foraging habitat, including beach wrack, was affected by oil. These sources of injury to western snowy plovers are accounted for in the assessment of shoreline/sandy beach injury, presented in the DARP.

Estimate of western snowy plover injury

Western snowy plovers at COPR in Santa Barbara County, and various locations within Ventura County, were exposed to Line 901 oil during the Refugio oil spill. The spill occurred during the breeding season, and at the time of the spill many nests had been formed and eggs had been laid. COPR was exposed to heavy oiling and extensive response actions, and the Trustees determined that an assessment of injury to this population was warranted. All western snowy plover populations in Ventura County were exposed to some level of tarball oiling and disturbance from response actions. Due to the relatively low injury expected from this oiling and disturbance, these effects are captured as part of the shoreline habitat injury assessment which considers impacts to western snowy plover's prey base and disturbances to their habitat from response actions.

Response workers and land managers at COPR worked closely together to minimize impacts to western snowy plovers from oil spill cleanup actions. Managers documented oiling on western snowy plovers at COPR and disturbances to the birds from the presence of cleanup crews; however, no mortality was recorded and hatching and fledging rates met or exceeded long term averages. Therefore, no substantial injury at COPR was estimated in 2015, beyond impacts to food webs (through depressed beach invertebrate populations) and response impacts that are quantified as part of the shoreline injury assessment.

The year following the spill (2016), western snowy plover infertility substantially increased compared to the long term average, with a total of 12 infertile eggs, none of which contained embryos. Background infertility under normal conditions is around 2%, therefore, of the 12 infertile eggs, 2 would be expected to occur without the effects of the spill. The additional 10 infertile eggs cannot be explained by background infertility rates. These infertilities were likely caused by exposure of western snowy plover adults to oil during the 2015 breeding season. Adults were observed with oil on their plumage and beaks, which they preened and ingested. Adults were also observed foraging within oiled wrack, and their prey species (e.g., sandy beach invertebrates, such as sand crabs) were documented to have increased hydrocarbons in their tissue (see Section 5.1 of the DARP). In 2017, the infertility rate was reduced to a level that is within the range of normal variation. Based on typical hatching and fledging rates at COPR, the Trustees anticipate that of the 10 infertile eggs documented at COPR in 2016, 4 would have hatched and fledged. Therefore, we assert that at least 4 western snowy plovers at COPR were injured through reproductive injury from the Refugio oil spill. Additional injury to western snowy plovers may have occurred from direct oil exposure, prey reduction, and impacts from response operations. These effects to plovers from injuries to their habitat are captured in the shoreline injury analysis presented in Section 5.1 of the DARP.

Other Bird Species Injury

Bird species other than brown pelicans and western snowy plovers were also impacted by the spill, includingat least 28 species of seabirds, shorebirds, and landbirds. Table 1 lists all the birds by species collected alive and dead during the spill response.

After pelicans, impacts were spread among a variety of marine waterbirds and a few landbirds. Because the spill occurred during the nesting season for most North American birds, and most affected species do not nest locally, the impacts to them were largely limited to non-nesting individuals, such as sub-adults that were likely over-summering in the area. Had the spill occurred in winter, many more individuals from these species groups would have been impacted.

In order to estimate mortality for these species, the Trustees applied the following methodology, which will be explained further in the sections below.

1) Determine which of the collected birds were related to the spill:
    a. Identify species and numbers of birds collected;
    b. Identify number of visibly oiled and non-visibly oiled birds;
    c. Visibly oiled dead birds – adjust for baseline oiling from natural seeps;
    d. Non-visibly oiled dead birds – adjust for background deposition; and
2) Use the Beached Bird Model to identify how many birds were missed:
    a. Determine carcass persistence on beaches;
    b. Determine search effort;
    c. Determine search efficiency;
    d. Subtract rehabilitation credit; and
    e. Calculate total injury.

Determining which of the collected birds were related to the spill

A portion of the live and dead birds collected during the spill response may not have been impacted by the spill. The Trustees analyzed the live and dead bird intake records to determine which animals were likely injured or killed by the spill and which were not. The methodology is described below.

Live birds

All of the 66 birds recovered live and transported to rehabilitation centers were assumed to be spill-related. Of those, 47 were brown pelicans and so are not included in this analysis (see Brown Pelican Injury Analysis section above). Of the remaining 19 birds, one live Pacific loon captured at the end of the spill period (on June 14, 2015) had oil on it that was analyzed and found not to match Refugio incident oil. The bird was removed from the total. The Trustees assumed that no birds collected after June 14, 2015, were related to the spill. Thus, 18 birds, other than pelicans, were collected alive and attributed to the spill.

Dead birds

Of the 203 birds collected dead, 26 were pelicans and so are not included in this portion of the analysis (see Brown Pelican Injury Analysis section above). Additionally, two domestic ducks

and one pigeon were removed from the total, as these non-native species are not protected under state and federal statutes. With these adjustments, the total number of dead birds used in this analysis was 174 birds. Of these, 85 were visibly oiled and 89 were not visibly oiled.

Dead birds- visibly oiled

Because natural oil seeps occur in the area (Henkel et al. 2014), a low number of oiled birds are regularly found. Thus, it is likely that some of the oiled birds collected during the spill response were oiled by natural oil seeps rather than the spill. Analyzing the petroleum fingerprint of oil from each bird carcass is both costly and possibly inconclusive, as results can be confounded by weathering and mixing of oil. To avoid this cost and ambiguity, the Trustees instead determined the background oiling rate of dead birds on impacted beaches using data from the BeachCOMBERS program. This rate was then applied to the oiled dead birds found during the spill response to determine the number of bird deaths assumed to be related to natural seeps rather than to the spill.

Eleven beaches within the spill zone are routinely surveyed as part of the BeachCOMBERS program, which counts and assesses bird carcasses for oiling status (among other factors) on a monthly basis. Historic oiling data (2013 to 2015) from birds identified on these eleven beaches for the months of May, June and July were analyzed to calculate a monthly average oiling rate for each beach. These months were selected because carcass deposition fluctuates during the year and these months are representative of the spill period.

Figure 23 illustrates the results, comparing the background number, per kilometer of beach, of dead oiled birds on the BeachCOMBER survey beaches with the number of dead oiled birds collected during the spill response on the same beaches. These data indicate that the number of oiled bird carcasses collected following the spill was significantly higher than the number observed in previous years, particularly on the west-facing beaches near Ventura, directly in the path of the oil. During the spill, an average of 0.83 oiled birds per kilometer were collected, compared with a historic average of 0.12 oiled birds per kilometer. This implies that 14% of the dead oiled birds collected were likely attributable to seep oil, and 86% were spill-related. Applying this background oiling rate to the 85 oiled dead birds (not including brown pelicans, the rock pigeon, or the two domestic ducks) collected during the response implies that 12 bird mortalities were likely not attributable to the Refugio incident and 73 were spill-related.

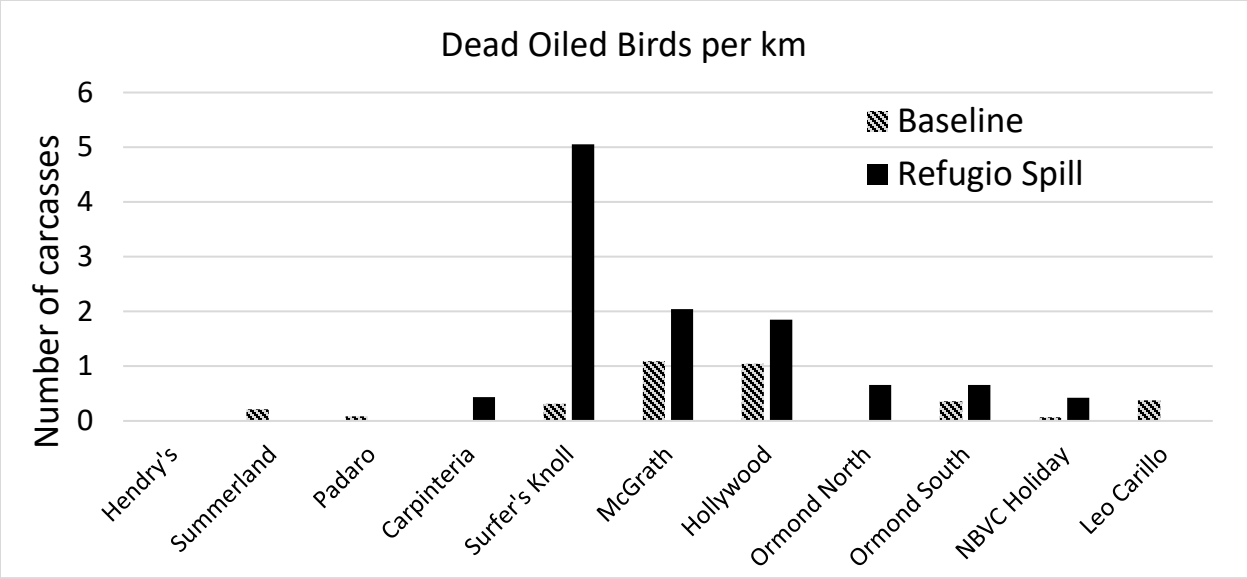


Figure 23. Dead oiled birds per kilometer collected during the response period (in black) compared with the baseline monthly average dead oiled birds per kilometer determined using data from the BeachCOMBERS program (in cross-hatch).

For purposes of the Beached Bird Model (described further below), rather than remove 12 of the birds from the list, without knowing which ones were actually seep-related mortalities, each of the 85 oiled dead birds were counted as 0.86 of a bird.

Dead birds- non-visibly oiled

Dead birds after an oil spill may not show any visible oil for a variety of reasons. The most common reason is that they are quickly scavenged, with the breast and belly feathers (where the oiling is most likely to occur) among the first feathers removed. As carcasses become old and desiccated, oiling becomes more difficult to detect. Nevertheless, it is common after an oil spill to see a spike in non-visibly oiled dead birds, suggesting they are related to the spill.

Of the 89 birds (not including brown pelicans, the rock pigeon, and domestic ducks) that were collected dead and not visibly oiled, the Trustees again relied on a comparison to baseline data from BeachCOMBERS survey beaches to detect a spill signal and estimate the difference between that spike and baseline numbers. Figure 24 shows the number of non-visibly oiled birds collected during the response compared with the average monthly number of non-visibly oiled birds calculated from the BeachCOMBERS data (i.e., baseline). Overall, following the Refugio oil spill, the number of non-visibly oiled birds collected was higher than the baseline number.

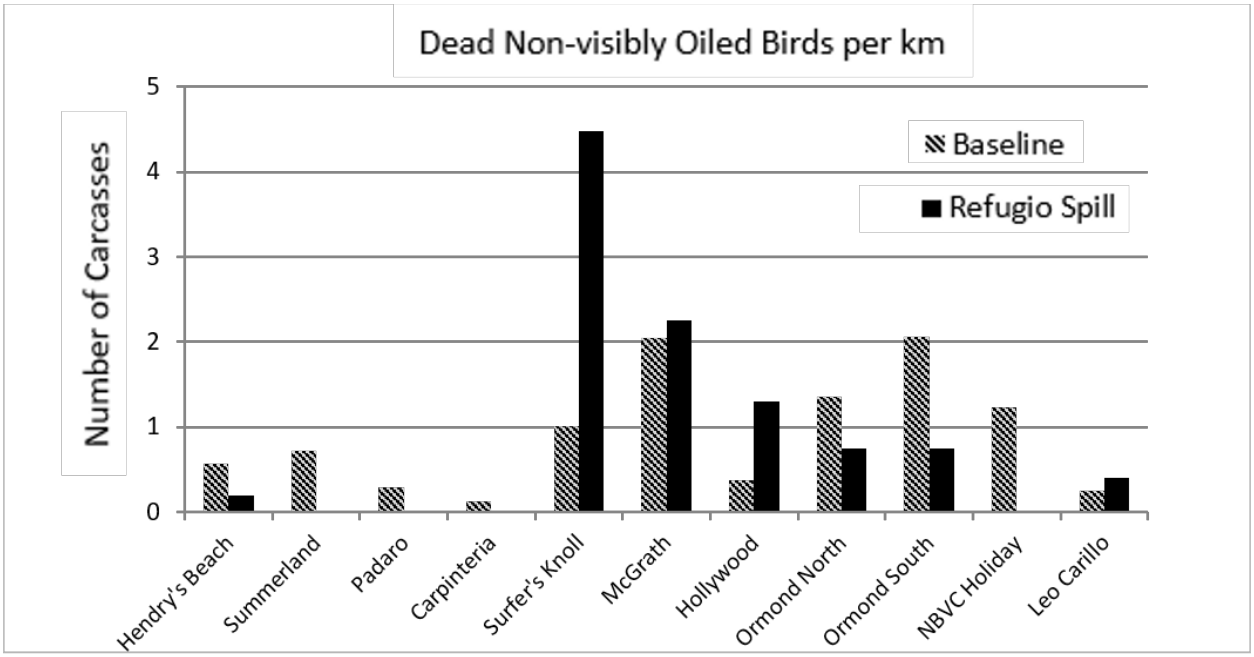


Figure 24. Dead non-visibly oiled birds per kilometer collected following the Refugio spill (black) compared with the baseline" monthly average calculated from the BeachCOMBERS data (cross-hatch).

To analyze these data further, the 89 non-visibly oiled dead birds were divided into three categories: fresh carcasses (n=23), decomposing carcasses (n=30), and fully desiccated carcasses ("mummies") (n=36). Carcass condition was recorded when dead birds were evaluated during intake. Historic BeachCOMBERS data also include these carcass delineations. Data from birds in each carcass category from the eleven beaches surveyed by BeachCOMBERS for the months of May, June and July were analyzed to calculate a monthly average deposition rate on each beach. These were compared to the analogous rates during the spill response period.

The results, tabulated in Table 6, show that fresh non-visibly oiled carcasses were found at nearly four times the rate that fresh carcasses are usually found, decomposing birds were found at about the same rate, and fewer mummified carcasses were found during the spill than would normally be expected. This implies that most of the fresh non-visibly oiled carcasses were likely due to the spill, some of the decomposing non-visibly oiled birds were likely due to the spill, and none of the mummies were likely due to the spill.

Table 6. Carcass condition of non-visibly oiled birds

	Baseline	Refugio Spill
Fresh	6%	22%
Decomposing	28%	26%
Mummified	53%	33%

These data were further analyzed to consider the fact that fresh and decomposing birds are disproportionately removed from beaches by scavengers, while mummies tend to persist for weeks. Taking this additional factor into account for purposes of the Beached Bird Model, the 23

fresh non-visibly oiled birds were counted as 0.70 of a bird. The 30 decomposing non-visibly oiled birds were counted as 0.37 of a bird. This method of applying an appropriate coefficient to each bird in these respective categories allows the model to weight fresh non-visibly oiled birds more heavily in the analysis and the non-visibly oiled birds less heavily, as appropriate due to the likelihood that each of these groups of birds should be attributed to the spill. All of the mummies were considered to pre-date the spill period and, thus, were removed from the injury calculations.

Total birds collected and attributed to the spill

All of the birds, not including brown pelicans, domestic ducks, and a rock pigeon, collected and attributed to the spill are shown in Table 7.

Table 7. All birds, not including pelicans, domestic ducks and a rock pigeon, collected and attributed to the spill.

	Total collected	Spill-related	Not-spill related	Total spill-related
Collected Live	19	95%	5%	18
Collected Dead				
Visibly oiled: spill-related	85	86%	14%	73
Not visibly oiled: fresh	23	70%	30%	16
Not visibly oiled: decomposing	30	37%	63%	11
Not visibly oiled: mummies	36	0%	100%	0
TOTAL	193			118

Calculating the number of birds missed

As with the brown pelican assessment above, it is very likely that the actual number of birds other than brown pelicans and western snowy plovers impacted by the spill exceeds the 118 enumerated above. Birds impacted by an oil spill may not be collected for a variety of reasons:

1. They may travel outside of the response area. As described above, this occurred with the large number of pelicans migrating north.
2. They may die at sea, sink, or be carried away by tides from beaches that were searched.
3. They may come ashore on inaccessible beaches that cannot be searched.
4. Once on the beach, they may be removed by other animals scavenging on the beach.
5. For carcasses that do make it to accessible beaches and are not removed by scavengers, searchers may miss them.

In this case, with the non-pelican species, it is difficult to assess the first two reasons. Some species, such as loons, were migrating north, but most non-pelican species may have been more acutely debilitated by the oil, limiting their dispersal distance. Because the spill was nearshore, substantial loss of birds at sea was unlikely. Given these caveats, we did not specifically apply any correction factors for these first two reasons for non-pelican bird species.

The remaining three factors, inaccessible beaches, carcass removal, and search efficiency, can be incorporated into a Beached Bird Model in order to estimate total mortality. The model is based

on the number of birds recovered, the probability of a beached bird persisting over a given time interval, and the likelihood that searchers will detect a beached bird. Derivation of the basic equation is from Ford et al. (1996) and Page et al. (1990). This approach has been used for most major oil spill bird mortality events for several decades. Using a simplified example, if the probability of a bird being removed by a scavenger in the course of a day is 50 percent, and the probability of it being overlooked by a searcher is 50 percent, then the probability of it being recovered is 25 percent. This would imply that for every bird found, three more are missed. This would result in a "beached bird multiplier" of four. That is, one bird found implies that four birds died.

The Beached Bird Model requires estimating the following parameters in order to calculate the deposition rate of dead and dying birds:

1. Carcass persistence on beaches;
2. Searcher effort; and
3. Searchefficiency.

Carcass Persistence

Carcass persistence was calculated based on BeachCOMBER data. During BeachCOMBER surveys, bird carcasses are marked by clipping a toe each time the bird is encountered. Surveyors document the number of clipped toes on each bird to document how long the carcass has persisted on the beach (e.g., a carcass with no clipped toes has not been previously found, 1 clipped toe is at least 1 month old, etc.). BeachCOMBER data collected between 2013 and 2015 from beaches within southern Santa Barbara and Ventura Counties were analyzed to determine carcass persistence in the spill-affected area. These data suggest that if 100 birds were encountered on Day 0, 32.3 will still be there on Day 30, and 12.3 will still be there on Day 60. Figure 25 shows these data fitted with a logarithmic curve mimicking the curves derived from past studies whereby carcasses disappear more quickly after initial deposition.

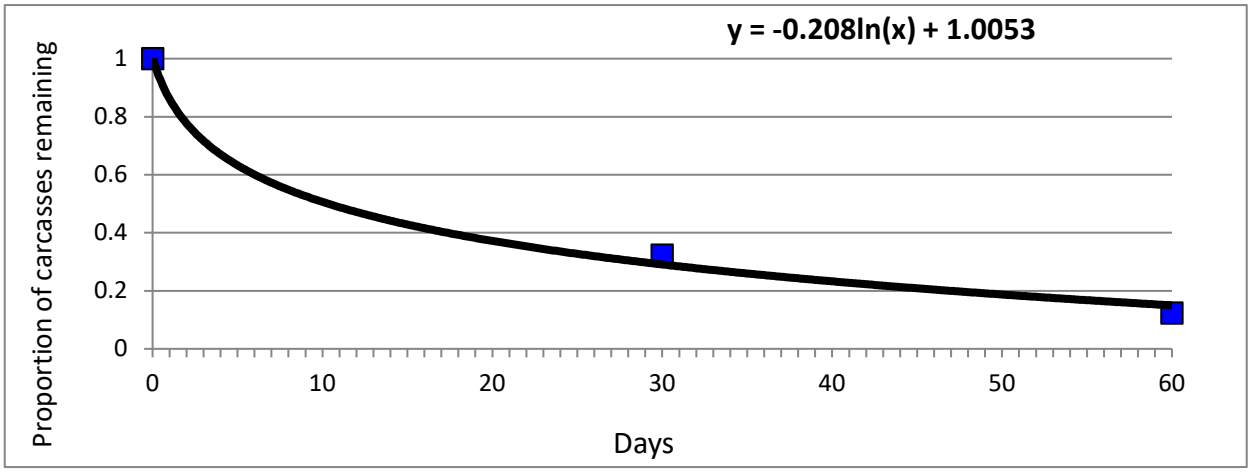


Figure 25. Carcass persistence based on BeachCOMBER data collected between 2013 and 2015 from beaches near the spill.

Because beaches are searched nearly daily during a spill response, the first week or two of the curve is the most relevant. Figure 26 shows estimated carcass persistence the first 1 to 14 days, and indicates that carcass persistence is about 60% after a week. This is similar to previous studies in northern California and Oregon.

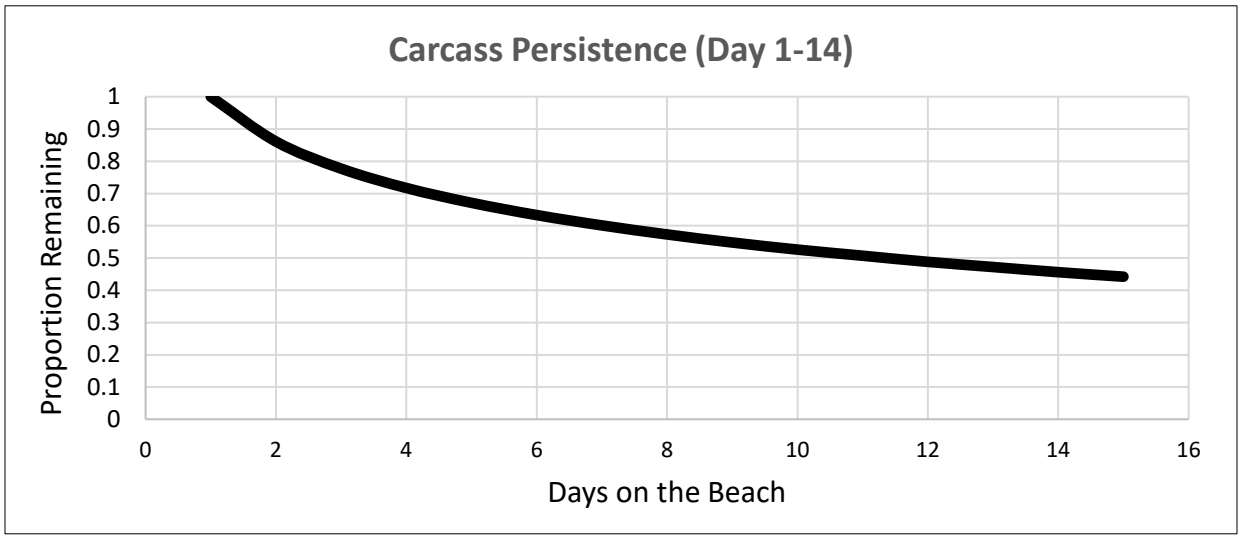


Figure 26. Calculation of carcass persistence in the first week of deposition.

Search Effort

The Beached Bird Model considers the proportion of beaches that were searched and unsearched. Search effort was calculated from the review of records throughout the spill of beach searches conducted by wildlife operations, cleanup crews, shoreline cleanup assessment technique (SCAT) teams, and other response activities. The results of this analysis are shown in Table 9 and were used in the Beached Bird Model. For beach segments that are never searched, the model simply averages the number from adjacent segments and applies that result to the unsearched segment. In this case, that factor was trivial, as nearly every beach between Gaviota and Point Mugu was accessible and searched. Many beaches were searched daily between May 20 and June 8.

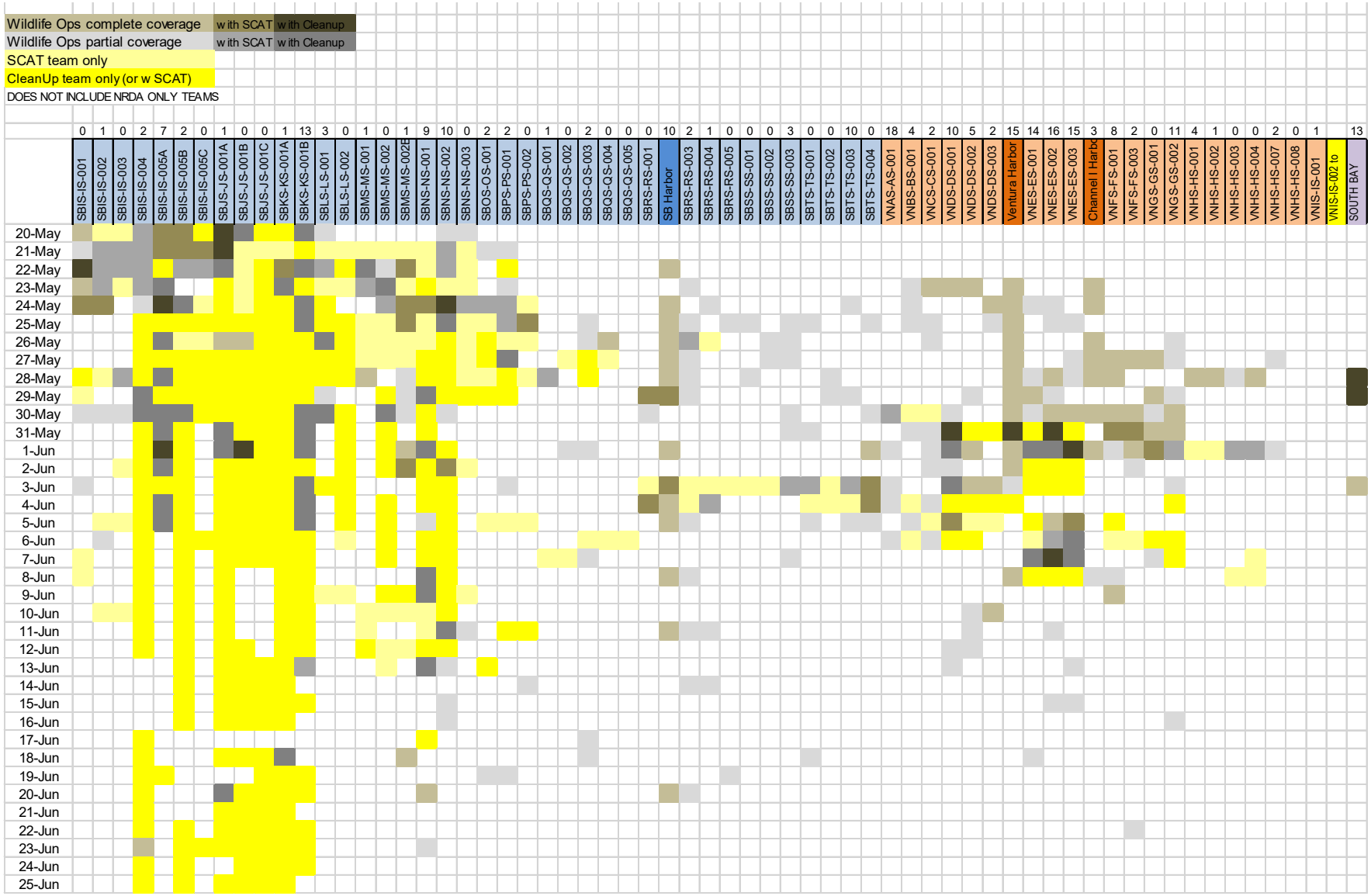
Search Efficiency

It is surprisingly easy for searchers to miss beached birds. Debris or wrack-filled beaches are visually difficult environments, and birds can be hidden in small depressions, blend in with other debris, or be too far away to recognize. Studies of search efficiency have been conducted previously following other oil spills in California. For this case, the Trustees chose to adopt search efficiency parameters determined through studies conducted during the M/V Kure oil spill and the S.S. Jacob Luckenbach oil spill (Ford et al. 2006, Luckenbach Trustee Council 2006). The search efficiency values used in this case are shown in Table 8. Different values are used for large birds than for small birds because large birds are inherently more identifiable and are less likely to be missed by searchers than small birds.

Table 8. Search Efficiency

Large Birds	0.54
Small Birds	0.206

Table 9. Refugio Oil Spill Search Effort by Date and SCAT Segment. Segments are listed from North to South starting with SBIS-IS001 near Gaviota, and ending with South Bay near Santa Monica.



Results of the Beached Bird Model

Based on the results of the Beached Bird Model (incorporating scavenging, search efficiency, and unsearched areas), the Trustees estimated that a total of 236 other birds were killed by the spill, not including brown pelicans and western snowy plovers.

Table 10. Summary of estimated mortality for "other birds" based on the results of the Beached Bird Model.

Bird Taxon	Total Birds Collected[1]	Total Estimated Mortality
Alcids	42	56
Loons	44	53
Procellarids/Boobies	23	35
Gulls/Terns/Skimmer	24	33
Cormorants	33	24
Grebes	15	21
Surf Scoter	3	6
Other/Unknown	9	8
TOTAL	**193**	**236**

[1]Not including pelicans, domestic ducks, a rock pigeon, and three rehabilitated and released birds. Note that a proportion of these carcasses were found to not be spill-related (see Table 7).

Rehabilitation Credit

Of the 18 non-pelican birds collected alive, only three were rehabilitated sufficiently to allow their release. All others died in care. These numbers are quite different from the corresponding figures for brown pelicans, for which 47 were collected alive and 43 released. The difference is largely because these non-pelican species were smaller and more sensitive to oiling than pelicans. The fate of the three released birds is unknown. Various post-release studies have produced a variety of results regarding the long-term survival of rehabbed and released birds. The results depend on species impacted and conditions in the field. For the purposes of this assessment, we will assume one of the three released birds survived and re-entered the breeding population (resulting in a rehabilitation credit of one bird).

Total Other Bird Injury

Applying the rehabilitation credit to the results of the Beached Bird Model results in a total of 235 birds injured by the spill (not including brown pelicans and western snowy plovers) as calculated below.

Total birds collected	193
Birds that were not related to the spill	-75
Estimated number of birds missed	+ 118
Rehabilitation credit	- 1
TOTAL Other Bird Injury	235

Summary of Bird Injury

Table 11. Total estimated bird mortality resulting from the Refugio Beach Oil Spill.

Bird Taxon	Total Estimated Mortality
Brown Pelicans	319
Western Snowy Plovers	4
Alcids	56
Loons	53
Procellarids/Boobies	35
Gulls/Terns/Skimmer	33
Cormorants	23
Grebes	21
Surf Scoter	6
Other/Unknown	8
TOTAL	**558**

Calculating Lost Bird Years

Lost bird-years were calculated several different ways, depending upon the species. Theoretically, lost bird-years are the difference between two different population trajectories: without the spill (baseline) and with the spill (injured). Without restoration, the two trajectories only converge (i.e., the injured population only recovers to baseline levels) if there is a natural compensating mechanism dependent upon population size (at least at the local, or colony, level). Thus, the calculation of lost bird-years must be consistent with a biological explanation of natural recovery over time (or lack thereof) (Zafonte and Hampton 2005).

The Single-Generation Stepwise Replacement Model was used to calculate lost bird-years. This approach is described below. For all bird-year calculations, a 3% discount rate is employed, consistent with common practice in natural resource damage assessments. The demographic parameters used in the bird Resource Equivalency Analysis are drawn from literature containing life history information for the species (see Injury Calculation section below).

Single-Generation Stepwise Replacement Model

The single-generation stepwise replacement approach to calculating lost bird-years assumes that each year after a spill the juvenile age class will be entirely replaced. That is, despite the fact that some breeding adults have been killed, the population produces the same number of juveniles post-spill as it did pre-spill. Biologically, this could occur if the population was at carrying capacity with respect to breeding opportunities (perhaps limited by available nesting habitat or food base during the nesting season). The loss of some adults would open up room for other adults (i.e. “floaters”) to take over the vacant nesting opportunities and, thus, maintain the population’s annual production of juveniles. Thus, the youngest age class impacted by the spill will fully recover to its pre-spill level after the next breeding season. The second-year age class will fully recover two years after the spill, as the recovered first-year birds grow older. Likewise, the third-year age class will fully recover after three years, and so on. Mathematically,

this is equal to calculating the number of years lost by the killed birds, based on the life expectancy of each age class. Details regarding the demographic parameters used to calculate lost bird years are presented in the "Injury Calculation" section below.

This method roughly follows the same approach as used for calculating "direct loss" for birds with "extended" recovery times in the *North Cape* oil spill, and Luckenbach NRDA. Calculations are based upon the following assumptions:

> ***Assumption 1:*** Acute spill mortality is distributed proportionately across the various age classes of the injured population.
>
> ***Assumption 2:*** Rates of juvenile and adult survivorship are constant before and after the spill.
>
> ***Assumption 3:*** The pre-spill and fully recovered populations are roughly constant in size and stable in age-distribution, as determined by demographic characteristics of the species (specifically survivorship and fecundity).
>
> ***Assumption 4:*** There is a maximum age beyond which no birds live.
>
> ***Assumption 5:*** Surviving adult birds match the total reproductive output that the surviving and impacted birds would have had in the breeding seasons after the spill had the spill not occurred (i.e. the number of post-spill nests equals the number of baseline nests). This could occur because of non-breeding "floaters" in the area, reduced competition for high quality nesting sites, or decreased competition for foraging around the breeding area.

Figure 27 provides an example of how these assumptions combine to describe biological recovery in a hypothetical population with three one-year age classes. Year -1 depicts the population's pre-spill conditions. Year 0 shows population numbers prior to the first full year after the spill. The shaded area is the number of each age class killed, which is distributed proportionately between age classes (Assumption 1). The arrows describe how the recovered birds advance through each age class.

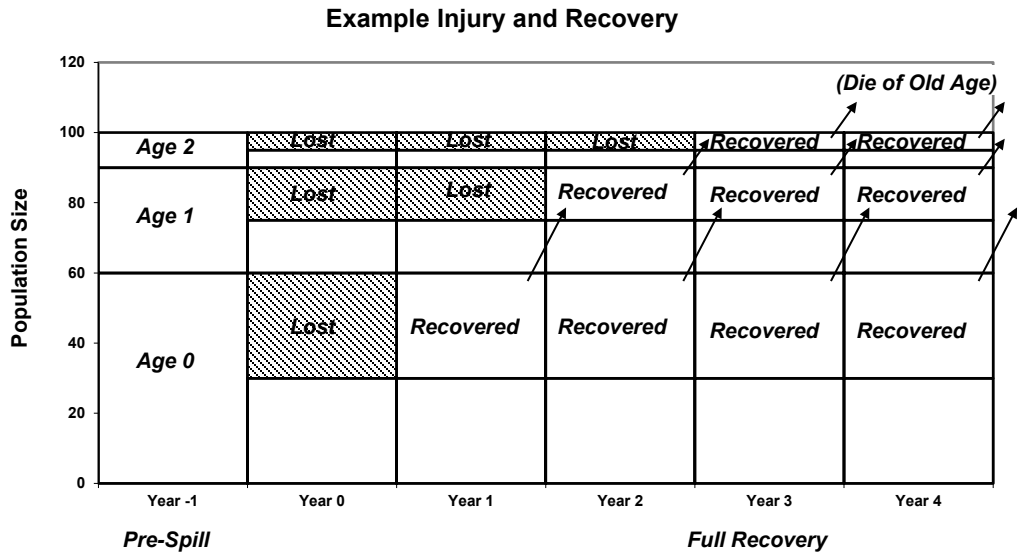


Figure 27. Example of recovery by age class over time

In Year 1, the number of fledglings replaces the losses to the first age class (Assumption 5). The age classes from Year 0 all face annual mortality with complete mortality for the third age class. This process continues in Year 2, with the recovered Age 0 juveniles from Year 1 facing mortality and growing one year older to reach Age 1. In Year 3, there is full recovery. These calculations do not include impacts to future generations of birds (i.e., "indirect loss" as considered by Sperduto et al. (1999, 2003).

Injury Calculation

As described earlier, the total estimated mortality for pelicans was 319, and the total for other seabirds was 235. Combined, these total 554 (not including the 4 western snowy plovers addressed elsewhere in the assessment).

To scale the size of the compensatory restoration projects to the size of the injury, the Trustees convert the total estimated mortality (554) into lost bird-years, using the single-generation stepwise replacement approach described above.

Because brown pelicans constitute the majority of the injury, and because the other seabirds have life-history parameters similar to pelicans on average, the Trustees used pelican life-history parameters to estimate lost bird-years. For brown pelican data, we relied upon Williams and Joanen (1974) and Anderson et al. (1996).

Brown Pelicans

- *Age of First Breeding:* 3 Years Old
- *Female Offspring per Female:* 0.33 (fecundity = 0.66)
- *Annual Survivorship (Age 3-4+):* 88%
- *Annual Survivorship (Age 2-3):* 80%
- *Annual Survivorship (Age 1-2):* 72%
- *Survivorship (From fledge to one year of age):* 64%
- *Maximum Age:* 34 Years

The result is that the bird-year multiplier, based on these life-history parameters for pelicans, is 6.28. This multiplier was then applied to the 554 estimated dead birds resulting in 3,479 discounted lost bird-years (554 x 6.28 = 3,479 discounted lost bird-years). The restoration projects proposed to compensate for these lost bird-years are scaled to create same the number of bird-years that were lost due to the spill.

Bird Injury Summary

In summary, the assessment of injury to birds from the Refugio oil spill was conducted by dividing all affected birds into three categories: brown pelicans, western snowy plovers, and all other birds. The assessment methods for each category were designed around the species' life-history strategy and feasible methods for quantifying injury. Based on the assessment, the Trustees estimated that approximately 319 brown pelicans, and 235 other birds were killed as a result of the Refugio Beach oil spill. Figure 28 shows the overall summary of estimated bird mortality by species group. Additionally, reproductive injuries to western snowy plovers at COPR resulted in the loss of at least 4 western snowy plovers, that would have hatched and fledged but for the spill.

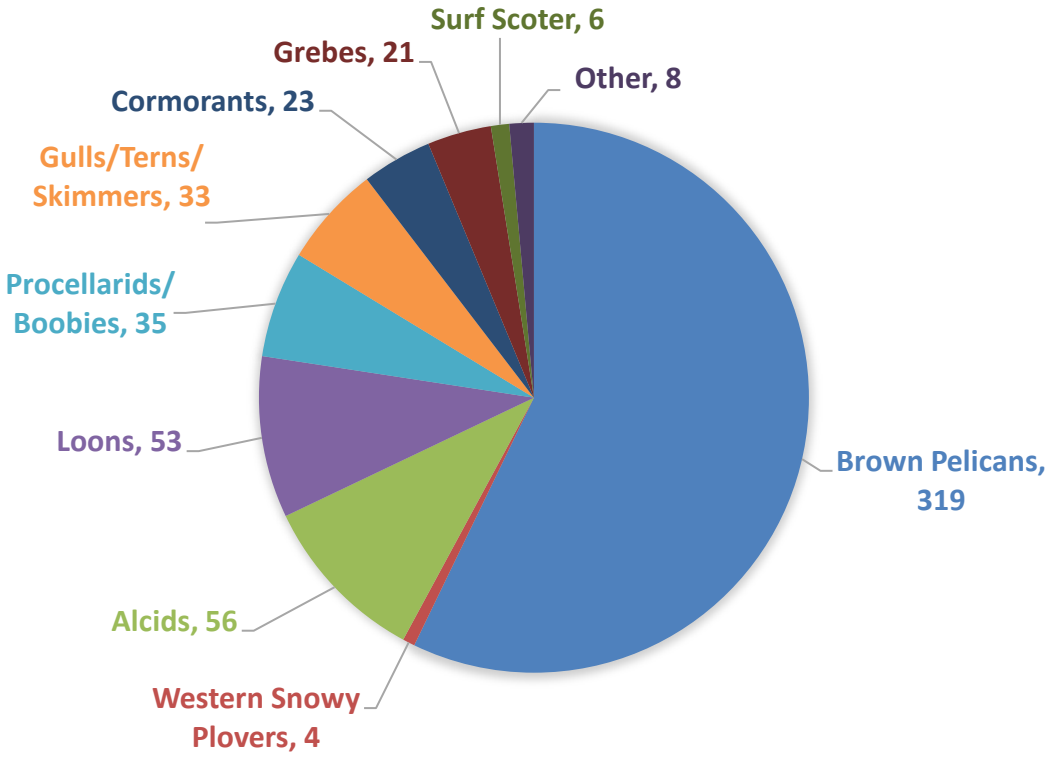


Figure 28. Estimated mortality of birds from the Refugio Beach oil spill (558 total) by species groups.

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